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INDEX.

CALEB MILLS SAVILLE,

President New England Water Works Association,

1917.

New England Water Works Association.

ORGANIZED 1882.

Vol. XXXI. March, 1917. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

REPORT OF COMMITTEE ON DEXTER BRACKETT MEMORIAL.

[*Read September 13, 1916.*]

Boston, September 1, 1916.

To the New England Water Works Association:

The Committee on Dexter Brackett Memorial submits its final report, accompanied by the medal which has been designed for it, and a draft of rules for its award.

History of the Memorial. At the convention of 1915, a committee was appointed to consider the practicability of establishing a memorial to Past-President Dexter Brackett, and the most suitable form of such memorial. In November, 1915, that committee reported recommending that such a memorial be established, and that it take the form of a bronze medal to be awarded annually for a meritorious paper; that it would cost a little more than one thousand dollars to establish such a medal, and that a comparatively few members had subscribed to a guaranty fund of nearly nine hundred dollars, thus insuring the success of such an enterprise.

The Association thereupon voted that a committee should be appointed to obtain subscriptions, procure designs for a medal and have dies prepared, and draft rules for the annual award. The present committee was appointed pursuant to that vote.

Organization and Work of the Committee. The committee organized with Frederic P. Stearns as chairman and Charles W. Sherman as secretary and treasurer. It has held but few formal meetings, most of its work having been accomplished by correspondence and by informal conferences.

Subscriptions. An opportunity to subscribe to the fund was presented to the entire membership of the Association, as it was felt that many who could not afford to make large contributions would wish to give something. It was made clear that the guaranty fund assured the success of the memorial, and that no one was expected to contribute unless he felt a personal interest in the matter, or a larger sum than he could well afford. The total amount received was $1 281.50, from 101 contributors; of this, $870 was received from 33 subscribers to the guaranty fund. The names of the subscribers are contained in an appendix to this report. (Appendix A.)

Design. Immediately after its organization, the committee began to inform itself about work of this character, and soon selected Mr. Theodore Spicer-Simson, of New York City, an artist of international reputation in the design of medals, as the designer of the Brackett Memorial. From its purpose it was obvious that one side of the medal should bear a portrait of Mr. Brackett, and the other a design typical of the Association and an inscription indicating the purpose of the award, the name of the recipient, and the date. Mr. Spicer-Simson has produced the medal presented at this time, photographs of which are attached to this report for record.

Rules for Award. The committee has devoted much thought to suitable rules for the award of the medal, and has prepared a draft of rules, which it submits herewith as Appendix B.

Fund to Provide for Payment for Medals and Cases. It was the desire of the committee that the establishment and maintenance of this memorial should not involve any draft upon the funds of the Association, and the contributions received have been sufficient to accomplish that result. After paying all its expenses, the committee has remaining the sum of $197.34, which is turned over to the Association herewith. This sum, if kept as a fund, would produce an income approximately sufficient to pay the annual cost of the medal and case, and engraving. We do not recommend that this sum be kept as a fund, but that, in consideration of its receipt, the Association assume the obligation of annually furnishing a medal and case, with suitable marking.

PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XXXI.
REPORT OF COMMITTEE ON DEXTER
BRACKETT MEMORIAL.

Receipts and Expenditures. As stated above, the committee has received subscriptions to the amount of $1 281.50, and interest on bank balances has amounted to $5.14, making a total of $1 286.64. The expenditures have been —

For design of medal and construction of dies........	$1 000.00
For 11 medals for N. E. W. W. A..................	22.00
For proof copy of medal, with case, for Mrs. Brackett,	5.25
Committee expenses, — stationery, printing, postage, express, etc..............................	62.05
Total................................	$1 089.30
Balance..................................	$197.34

which, as stated above, is now transmitted to the Association as approximately the capitalized cost of striking off and engraving medals and furnishing cases.

Respectfully submitted,

FREDERIC P. STEARNS,
ALLEN HAZEN,
ALFRED D. FLINN,
GEORGE A. STACY,
CHARLES W. SHERMAN,
Committee.

This report was accepted by vote of the Association on September 13, 1916 (xxx, 493).

At the meetings of the Executive Committee on January 10 and 29, 1917, the following gentlemen were chosen as the Committee on Award: Desmond FitzGerald, M. N. Baker, A. E. Martin.

APPENDIX A.

CONTRIBUTORS TO THE DEXTER BRACKETT MEMORIAL.

*Allardice, E. R. B.

Barbour, F. A.
Barrows, H. K.
Bell, D. V.
Bemis, E. W.
Benzenburg, G. H.
Booth, G. W.
Brooks, E. C.
Brown, A. W. F.
Bryant, H. F.
Burnie, James

Chase, J. C.
Clarke, D. D.
*Coggeshall, R. C. P.
Columbian Iron Works
*Conard, W. R.
*Connet, F. N.

*Davis, J. P.
Doane, A. O.
Dockweiler, J. H.
Doherty, M. J.
Dunn, L. F.
Dwyer, T. E.

Earl, G. G.
*Eddy, H. P.
Eglee, C. H.

Fay, F. H.
Ferguson, S. F.
*FitzGerald, Desmond
*Flinn, A. D.
*Forbes, F. F.
*Foss, W. E.
*Freeman, J. R.
Frost, G. H.
Fuller, F. L.
Fuller, G. W.

Gilchrist, G. E., Co.
*Glover, A. S.
*Goodnough, X. H.
*Gould, J. A.

*Haberstroh, C. E.
Hale, R. A.
Harrison, Samuel
Hathaway, A. R.
Hazard, T. G., Jr.
*Hazen, Allen
Heffernan, D. A.
Hill, A. B.
Hill, N. S., Jr.
Houdlette, F. A., & Son
*Howard, J. L.
*Howe, E. W.

Kent, Willard
*Killam, S. E.
Kimball, F. C.
King, G. A.
*Knowles, Morris

Lea, R. S.
Lochridge, E. E.
Looney, E. J.

Main, C. T.
Martin, A. E.
Maury, D. H.
Mayo, John
Merritt & Chapman Derrick & Wrecking Co.
*Metcalf, Leonard
Miller, H. A.
*Mills, H. F.
Moran, J. W.
Mueller, H., Mfg. Co.

Porter, Dwight

Quinn, E. W.

Ridgway, Robert
Robinson, L. C.

*Sando, W. J.
*Saville, C. M.
*Sherman, C. W.
Sherrerd, M. R.
Smith, A. P., Mfg. Co.
*Smith, J. W.
Spofford, C. M.
Stacy, G. A.
*Stearns, F. P.
Stearns, R. H.
Sullivan, W. F.
Swain, G. F.

Taylor, W. P., Co.
Tighe, J. L.
*Tilden, J. A.
*Tinkham, S. E.
Tower, D. N.

United States Cast Iron Pipe and Foundry Co.

Walsh, J. H.
*Weston, R. S.
Wheeler, William
*Whipple, G. C.
Wilkins, F. B.
Williams, G. S.
*Winslow, F. I.
Wood, Walter
*Woods, H. D.

33 guarantors; 101 contributors.

* Contributors to the guaranty fund.

APPENDIX B.

Suggested Rules Governing the Award of the Dexter Brackett Memorial Medal.

The Dexter Brackett Memorial has been established by contributions to perpetuate the memory of Dexter Brackett, who was president of the Association for the year 1889–1890.

In consideration of the donation of the dies and an accompanying fund, the Association has assumed the responsibility for the payment in perpetuity for the Dexter Brackett Memorial Medal.

Committee on Award.

1. The Executive Committee shall annually appoint three members of the Association who shall constitute a committee to recommend the award of the Dexter Brackett Memorial Medal for the preceding year. This appointment shall be made not later than the regular meeting in February. Members of the Executive Committee shall not be eligible for appointment upon the Committee on Award, nor shall the author of any paper which is to be considered by the committee.

2. The papers to be considered shall include all papers written by members of the Association and published in the volume of its Journal for the calendar year for which award is to be made.

3. The committee shall report its recommendations to the Executive Committee on or before August 1, and the award shall be made by the Executive Committee. The announcement of the award and presentation of the medal shall be made at the annual convention.

Rules for Award.

1. Competition for the medal shall be restricted to members of the New England Water Works Association.

2. There shall be one bronze medal awarded annually, unless, in the opinion of the Committee on Award, no paper shall have been published of sufficient merit to receive the award.

3. Any original paper presented to the Association by a member, and published in the volume of the Journal for the calendar year for which the medal is to be awarded, shall be open to the award, provided that such paper, or an important part thereof, shall not have been previously contributed to any other society, nor have appeared in print prior to its presentation to the Association, nor have been published in the Journal in any previous year.

4. The medal shall be awarded for the paper which is judged to be most meritorious, bearing in mind its applicability to general water-works problems.

REPORT OF COMMITTEE ON GRADING WATER WORKS WITH REFERENCE TO THEIR VALUE FOR FIRE PROTECTION.

[*Presented September 15, 1916.*]

Necessity for Grading of Cities.

It is obvious that in any attempt to equitably fix fire insurance rates, some scheme of classifying or grading of cities must be adopted, in which all features which affect liability to fires and the facilities for extinguishing them should be taken into account.

In the past, methods of grading for insurance purposes seem to have been of a haphazard character, at least in so far as water works were concerned, and it has been impossible to obtain any definite information which would enable one to judge in advance what modifications in grading would result from establishing, or from a radical improvement of, a water-works system. It has therefore been impossible, as a rule, for water-works engineers or superintendents to indicate what saving in insurance premiums might be expected as the result of any particular improvement in fire protection resulting from improved water works.

It is obvious that the formulation or adoption of a system of grading will not of itself adjust insurance rates. These rates are established by local boards or commissions, not all of which base their grading upon the same subdivisions into groups or classes, and of course the rates fixed in various districts are often widely divergent. The adoption of a scientific uniform scheme of grading is nevertheless the first step towards a systematic and scientific scheme of establishing rates, and after the adoption of a standard scheme of grading, it would be possible to estimate what improvement in grading would result from any contemplated change in the water-works system and thus compute, at least approximately, what saving in insurance rates can be obtained in view of the rates locally in force.

Grading Schedule Proposed by National Board of Fire Underwriters, 1915.

The first attempt at a scientific schedule for grading cities and towns with reference to fire defense and physical conditions was prepared by the engineers of the National Board of Fire Underwriters in 1915. This was done as a necessary preliminary to the attempt of the actuarial bureau of that Board to classify fire losses and from the study of data thus obtained to establish a basis of scientifically fixing insurance rates.

The grading schedule proposed by the National Board is based on several years of careful investigation by their engineering staff, of the fire protective features of cities throughout the United States. It is based upon a plan of assigning to the various features of fire defense, points of deficiency depending upon the extent of variance from standards formulated by a study of conditions in more than five hundred cities, the natural and structural conditions which increase the general hazard of cities, and the lack of laws or of their enforcement for the control of unsatisfactory conditions. The sum of the maximum points of deficiency is 5 000, divided in accordance with the relative features considered, as fixed by the engineers of the National Board, as follows:

Relative Values.

			Points.	
Water supply	Engine stream basis			1 700
	Hose stream basis	2 000		
Fire department	Engine stream basis			1 450
	Hose stream basis	1 150		
Fire alarm			550	
Police			50	
Building laws			200	
Explosives and inflammables			200	
Electricity			150	
Natural and structural conditions			700	
	Total,		5 000	

The classification based on this schedule is as follows:

A 1st Class	City or Town is one	receiving from 0 to	500 points of	deficiency.
A 2d	do.	do.	501 to 1 000	do.
A 3d	do.	do.	1 001 to 1 500	do.
A 4th	do.	do.	1 501 to 2 000	do.
A 5th	do.	do.	2 001 to 2 500	do.
A 6th	do.	do.	2 501 to 3 000	do.
A 7th	do.	do.	3 001 to 3 500	do.
An 8th	do.	do.	3 501 to 4 000	do.
A 9th	do.	do.	4 001 to 4 500	do.
A 10th	do.	do.	more than 4 500 points, or without any fire protection.	

The detailed schedule in its present form is appended to this report as far as it relates to water-works features. Trial applications of the schedule have been made by the engineers of the National Board to about two hundred cities and towns of various sizes in different parts of the country; as a result, some changes and additions have been made, mostly in the nature of amplifications. It is probable that, in years to come, experience will show further revision of like nature to be desirable.

Reasons for Interest in Insurance Grading on Behalf of the New England Water Works Association.

It may be that some question will arise as to the propriety or desirability of the New England Water Works Association interesting itself in a matter which, on the face of it, has to do only with the grading of cities for insurance purposes. The manner in which water-works men may utilize schedules for grading has already been suggested. It must not be forgotten, too, that the engineers of the insurance companies are as a rule hydraulic or water-works engineers who are devoting themselves to advising their employers, the insurance companies, with relation to the efficiency for fire fighting of the water-works systems, so many of which are in the control of members of this Association. To be sure, the insurance engineer studies also the effect of many other features upon fire hazards and fire protection, but almost all of them have to do with the facilities for quickly and advantageously utilizing the protection afforded by our water-works systems.

It is obviously desirable, therefore, that the engineers grading these systems with a view to their value for fire protection, and the men in control of the water works, should agree as to the methods and points by which rating shall be arrived at. Constructive criticism on a standard grading schedule should therefore be obtained, not alone from the engineers engaged in making such rating, but also from the men having to do with the construction, operation, and maintenance of our water-works systems.

With this idea in view the New England Water Works Association passed a vote in February, 1916, authorizing the appointment of the present committee.

Progress Report of Committee.

This committee wishes at the outset to call attention to the notably friendly spirit manifested by the National Board of Fire Underwriters, which has welcomed our criticism and has coöperated with us in every way, sending its chief engineer, Mr. George W. Booth, and his principal assistant, Mr. Clarence Goldsmith, both of whom are members of this Association, to confer with us in Boston. In short, the National Board has shown an open and above-board policy, and a willingness to recognize the New England Water Works Association, and the assistance which it could afford, that augurs well for a better future understanding between the water-works and the insurance interests.

The committee has given the proposed schedule careful study, and, considering it as a whole, is satisfied that it is a long step in the right direction. Until the committee has had opportunity to study the results of the application of the schedule to systems with which its members are familiar, criticisms of the detail, and particularly of the number of points of deficiency assigned to various features, are not of controlling significance at the present time. The classification, when effected, will in the nature of things have a direct bearing upon the actual insurance rates, particularly when studied in connection with the data relating to actual losses now being classified and arranged by the actuarial committee of the National Board. It is inconceivable that the rates should continue to be assessed in the present illogical and

oft-times unfair manner. The practical and most desirable result fairly to be expected to follow the adoption of the schedule, as was noted above, is the possibility of determining with reasonable accuracy the saving in insurance that will result from a given expenditure for improvements in a water-works system. In other words, it will be possible in designing a new system or improving an old one to estimate upon probable insurance rates, just as comparative construction costs are now figured.

In the meetings of the committee considerable criticism developed in regard to certain fundamental provisions of the schedule. After full and free discussion with the engineers of the National Board, we found that many of the questions raised by us were the same as those which they had met and discussed in their earlier study of the problem, and we are now satisfied that the schedule in its present form is a well-considered one.

Certain modifications have been made at our suggestion, and others are now under consideration. In two respects, however, we have been unable thus far to fully agree with the engineers of the National Board or to convince them of the equity, from their point of view as well as of ours, of certain changes which it seems to us should be made. First, no penalty is assigned to too frequent or unduly large fire pipe connections from distribution systems, nor are rules which should obtain in regard to the granting of such connections considered in the schedule. We fully recognize the imperative need of connections of sufficient size for fire defense, but we equally recognize the necessity of adequately safeguarding them. Water in our mains should be used for fire protection just as poisons are used in medical practice: to cure and not to kill the patient.

The second issue is in regard to the right to existence of the so-called 4-in. hydrant. As submitted to us, the grading schedule would penalize this hydrant under all conditions, since none of the 4-in. hydrants can meet the stipulations as to capacity and friction loss. We fully recognize that the 4-in. hydrant has no place in urban conditions, but we are unable to agree that the same is true under all conditions, and we feel that the logical course is to recognize that the small hydrant, like the smaller sizes of pipe, has its proper sphere. The 4-in. hydrant should be

severely penalized in city practice; but in districts where the pipes are properly small and where the necessity of anything more than a single comparatively small fire stream is practically non-existent, we believe that no deficiency should be charged on account of the use of the 4-in. hydrant.

Recommendations.

The vote under which this committee was established instructed it to report whether or not it was desirable for the Association to indorse this or any similar schedule. Your committee is fully in accord with the principle of the schedule under consideration, but does not think it wise nor desirable to pass any vote of endorsement at the present time, in advance of its final adoption by the National Board, and in view of possible slight modifications before it reaches its final form. No action of the Association is therefore recommended at the present time. It is believed, however, that members of the Association confronted with problems of this nature will be materially assisted by the schedule, even in its preliminary form, and that coöperation with the engineers of the National Board will result in further perfecting it.

The above is presented as a report of progress.

Respectfully submitted,

F. A. McInnes,
C. M. Saville,
Henry V. Macksey,
R. J. Thomas,
Charles W. Sherman,
Committee.

August 23, 1916.

APPENDIX.

PROPOSED STANDARD SCHEDULE FOR GRADING CITIES AND TOWNS OF THE UNITED STATES WITH REFERENCE TO THEIR FIRE DEFENSES AND PHYSICAL CONDITIONS.

NATIONAL BOARD OF FIRE UNDERWRITERS, NEW YORK, 1915.

Introductory.

The Grading Schedule is based upon the plan of assigning to the various features of fire defense found in cities of the United States, points of deficiency depending upon the extent of variance from standards formulated from a study of conditions in more than 500 cities, towns, and villages; the natural and structural conditions which increase the general hazard of cities, and the lack of laws or of their enforcement for the control of unsatisfactory conditions, are graded in the same way. The sum of the maximum points of deficiency totals 5 000 and is divided in accordance with the relative values of the features considered as given below.

Relative Values.

			Points.	
Water supply	Engine stream basis			1 700
	Hose stream basis	2 000		
Fire department	Engine stream basis			1 450
	Hose stream basis	1 150		
Fire alarm			550	
Police			50	
Building laws			200	
Explosives and inflammables			200	
Electricity			150	
Structural conditions			700	
			5 000	

A good water supply in connection with a poor fire department, or *vice versa*, is of less value than if both are good. In recognition of this, a modification of the better one of the two features is made, provided the divergence exceeds the equivalent of three classes.

In determining the points of deficiency to be applied to many of

the items, it appears reasonable to use a graduated scale of points depending upon the per cent. of deficiency, with a lesser increment for the first 30 per cent. than for the remainder; that is, a deficiency of 10 per cent. in good or moderately good conditions has less actual effect than where conditions are poor. Such a scale has been prepared and is given below; either the full scale, a multiple or a fractional part thereof is used, depending upon the relative weight or importance of the item under consideration.

DEFICIENCY SCALE.

(Points of deficiency corresponding to per cent. deficient.)

		10%.	20%.	30%.	40%.	50%.	60%.	70%.	80%.	90%.	100%.
		10	25	45	67	90	112	134	156	178	200
1%	1	12	27	47	70	92	114	136	158	180	
2%	2	13	29	50	72	94	116	138	160	182	
3%	3	15	31	52	74	97	119	141	163	185	
4%	4	16	33	54	76	99	121	143	165	187	POINTS
5%	5	18	35	57	79	101	123	145	167	189	
6%	6	19	37	59	81	103	125	147	169	191	
7%	7	21	39	61	83	105	127	149	171	194	
8%	8	22	41	63	85	108	130	152	174	196	
9%	9	24	43	65	88	110	132	154	176	198	

To save space, this scale is printed in full above, and reference is made to it under each item to which it applies.

In all items, the total required quantity or the total required number must be used as the basis in figuring the percentage of deficiency, except that under Water Supply, if there is a deficiency under Item 6 *a*, the quantity available on which this deficiency was obtained shall be used as a basis in figuring the percentage of deficiency of Items 7 to 16, inclusive, except for the item on which the inadequacy occurs, in which case the total required quantity

will be used. Where quantity or numbers cannot be used as the basis, as in Items 2, 7, 10, 11, and 17 of Water Supply, the degree of deficiency shall be graded approximately as follows: Slight, 10 per cent.; moderate, 25 per cent.; considerable, 50 per cent.; serious, 75 per cent., and total, 100 per cent.

Subjects Considered in the Schedule.

Water Supply.

Item.

1. Appointment of Employees.
2. Efficiency of Executive.
3. Records and Plans.
4. Emergency Repair Provisions.
5. Receipt of Alarms by Department.
6. Normal Adequacy of Entire System.
7. Reliability of Source of Supply.
8. Sufficiency of Reserve Pump Capacity.
9. Sufficiency of Reserve Boiler Capacity.
10. Condition of Equipment.
11. Fuel Supply or Electric Power.
12. Construction of Pumping Station.
13. Fire Protection of Pumping Station.
14. Hazards of Pumping Station.
15. Exposures to Pumping Station.
16. Reliability of Supply Mains as Affecting Adequacy.
17. Reliability of Installation of Supply Mains.
18. Completeness of Arterial System.
19. Reliability of Installation of Mains.
20. Effect of Small Mains in the High Value District Considered.
21. 4-in. Mains in System.
22. Dead Ends — 4- and 6-in. Mains.
23. Completeness of Gridiron of 6-in. Mains.
24. Quality and Condition of Pipe.
25. Electrolysis.
26. Spacing of Gate Valves.
27. Condition of Gate Valves.
28. Distribution of Hydrants in the High Value District Considered.
29. Ditto in Residential Districts.

30. Condition of Hydrants.
31. Small Hydrants.
32. Valves on Hydrant Branch.

NOTE. — The items covered under Fire Department, etc., are omitted in this report.

Classification of Cities and Towns Based on the Relative Number of Points of Deficiency in Fire Defenses and Physical Conditions.

A First Class City or Town is one receiving	0 to 500 points of deficiency
A Second Class City or Town is one receiving	501 to 1 000 points of deficiency
A Third Class City or Town is one receiving	1 001 to 1 500 points of deficiency
A Fourth Class City or Town is one receiving	1 501 to 2 000 points of deficiency
A Fifth Class City or Town is one receiving	2 001 to 2 500 points of deficiency
A Sixth Class City or Town is one receiving	2 501 to 3 000 points of deficiency
A Seventh Class City or Town is one receiving	3 001 to 3 500 points of deficiency
An Eighth Class City or Town is one receiving	3 501 to 4 000 points of deficiency
A Ninth Class City or Town is one receiving	4 001 to 4 500 points of deficiency

A Tenth Class City or Town is one receiving more than 4 500 points; or without a water supply and having a fire department grading tenth class; or with no fire protection.

Standard Grading Schedule.

Water Supply.

It is recognized that a so-called gravity system, i.e., one delivering supply directly to the city from the source without the use of pumps, is preferable from a fire protection standpoint, but a well-designed and properly-safeguarded direct pressure system, such as the high-pressure fire systems of some of our large cities,

so nearly approaches the gravity system in adequacy and reliability that no distinction is made between the two types.

The introduction of storage, either elevated and supplying the distribution system or for suction supply, offsets to a greater or less degree the need of duplication in various parts of a system, the value of the storage depending upon its amount and location; as affecting reliability of supply, it appears to be a reasonable assumption that a storage sufficient to meet maximum consumption demands for five days and leave a ten-hour fire flow available is sufficient to permit the making of most of the repairs, alterations, or additions incident to the operation of a water-supply system, and this assumption will be used as a basis in determining the extent of deficiency under Items 8, 9, and 16. The amount of storage and the probable time required to make repairs shall be taken into consideration in deciding on the degree of unreliability of Items 7, 10 to 15, and 17. In general, all storage lessens the requirements of those parts of the system through which supply has already passed. In no case can a rate in excess of the actual capacity of the mains from the storage be considered. Owing to the decrease in pressure when water is drawn down in standpipes, only the capacity of the top twenty-five feet can be considered as storage, unless situated on elevated ground and supply is to fire engines. Where storage fluctuates as much as 10 per cent. during the twenty-four hours, the minimum storage maintained must be used in the calculations. Capacity of pumps shall be considered on basis of present capacity, with proper allowance for loss due to condition.

The ability to utilize emergency supplies through connections to another system, or from a separate source or storage not normally used, must be considered in charging for deficiencies in the system under consideration, and credit given for the supply thus available at such pressures as may be required for adequate protection. These supplies are divided into two groups:

First, those owned or controlled by the same management as the system. Full credit may be given under items of reliability (Items 7 to 17, inclusive), where the supply comes in automatically or where definite arrangements are made for quickly drawing from the emergency supplies, with detail plans on file, showing

locations of gates and pipe lines. If no such arrangements and plans, or the emergency supplies, because of pollution, would be used only after conflagration conditions existed, credit shall be given for only one half the points which these supplies decrease the deficiency of the system. Under adequacy (Item 6) the above credits will be made only where the emergency supply can be turned in within thirty minutes, unless sufficient storage is available to maintain adequate supply for a period of two hours.

Second, those under outside control, where no contract agreement provides for their utilization by the employees of the system. These shall be applied only for Items 7 to 17, inclusive, under which credit shall be given for one third the points by which the quantity available from these supplies decreases the deficiency of the system.

Where a system is supplied from two or more sources of supply works, or where there are two or more systems serving the same area, the source or system furnishing the maximum protection shall be considered as the primary one; if one system is available at direct hydrant stream pressure, the low-pressure system may be considered only up to $\frac{3}{2}$ the engine capacity available. Application shall be made to the primary source or system, the deficiency of which is to be offset in whole or in part in any individual item by the additional protection afforded by the secondary source or system. Where the system graded covers only the district considered, Items 21 to 32, inclusive, must be based in whole or in part on conditions in the other system. In grading cities where high-pressure fire systems furnish protection to only a part of the district considered, separate gradings shall be made for the part thus protected and the part distant 300 ft. from the boundary hydrants of the area protected.

Where a water system exists, and canals, streams, ponds, wells, and cisterns make suction supply for engines also available, the suction supply may be considered in its ability to offset the deficiency in the various items where it would apply, but not in excess of the engine capacity available; in general, the only items affected will be Nos. 20, 28, and 29. Where no water system exists, such suction supply shall not be graded under Water Supply, a full deficiency of 1 700 points being allowed; the availability

of such supplies shall be considered in estimating the value of engine capacity and hose, as outlined in the Short Method of Grading Fire Departments.

The requirements given hereinafter are based in part upon the assumption that the maximum daily consumption is 50 per cent. in excess of the average, but in all cases of application the actual average consumption for the year previous shall be taken as the average consumption, and the maximum consumption for any twenty-four hours in the past three years taken as the maximum consumption, unless conditions have so changed that this maximum will not occur again.

In estimating required fire flow, an allowance is made for probable loss from broken service connections incidental to a large fire. Including this allowance, the total fire flow which should be available is approximately as given in the table below (based on formula $G = 1\,020\sqrt{P}\,(1 - .01\sqrt{P})$, where G = gallons per minute and P = population in thousands); but in all cases consideration must be given to the structural conditions as found in the city and also to the number of companies in the fire department and the amount of outside aid that would be called upon in case of a serious fire. The ratio of the total engine capacity to the fire flow required will be approximately as 2 to 3.

Population.	Required Fire Flow, Gallons per Minute, for the Principal High-Value District for an Average City.	Population.	Required Fire Flow, Gallons per Minute, for the Principal High-Value District for an Average City.
1 000	1 000	28 000	5 000
2 000	1 500	40 000	6 000
4 000	2 000	60 000	7 000
6 000	2 500	80 000	8 000
10 000	3 000	100 000	9 000
13 000	3 500	125 000	10 000
17 000	4 000	150 000	11 000
22 000	4 500	200 000	12 000

Over 200 000 population, 12 000 gal. a minute, with 2 000 to 8 000 gal. additional for a second fire.

In residential districts: For villages or towns under 10 000 population, 500 to 1 000 gal. a minute, where the district is not congested; for cities over this population, or where the district is congested, 1 000 to 3 000 gal. a minute, with up to 6 000 gal. a minute in densely built sections of three-story buildings.

In considering the adequacy of the domestic water supply under Item 6, *a* and *b*, the fire flow is assumed in all cases as being

delivered to the district considered at a pressure requiring the use of fire engines; that is, the pressure under full flow must not drop below 20 lb., except that a minimum of 10 lb. is permissible in districts having no deficiency in Items 28 and 31 and having all hydrants provided with at least one steamer outlet. If pressures are sufficient to permit direct hydrant streams, the need of fire engines is considered as offset, except for high buildings as required in Item 13 *b*, Fire Department. Where a deficiency exists in both engine capacity and direct hydrant streams, and the deficiency is greater in the former, consideration may be given under Item 6 *c* to the deficiency in fire flow at direct hydrant stream pressure. When application is not made under 6 *c*, all items figured to 20 lb., except as noted where no engines are available. For direct hydrant streams, a residual pressure of at least 75 lb. is required in high-value districts, except that where not more than ten buildings exceed three stories, a residual of 60 lb. is permissible. In closely built residential districts, a residual of 60 lb. is considered sufficient for direct hydrant streams; in thinly built residential sections, or in villages where buildings do not exceed two stories in height, a residual pressure of 50 lb. is considered sufficient.

When pressures permit direct streams and $\frac{3}{2}$ the engine capacity is not in excess of the quantity thus available, Items 8, 16, 18, 20, 21, 22, 23, and 28, Water Supply, shall be considered in respect to the ability to deliver water at direct hydrant stream pressure, except that where a deficiency exists in Items 8 and 16 at hydrant stream pressures, an allowance for fire flow at less pressure may be made, not to exceed $\frac{3}{2}$ the total actual engine capacity in service in the Fire Department.

1. Appointment. Employees on municipal systems to be under adequate civil service rules, properly administered, with tenure of office secure. Long tenure of office and an efficient organization considered the equivalent.

Appointments not under civil service for indefinite terms. Use $\frac{1}{10}$ Deficiency Scale.

2. Chief Executive (superintendent or chief engineer) to be

competent and qualified by experience, preferably supplemented by education, to efficiently fill the office.

Inexperienced or incompetent: Use $\frac{1}{10}$ Deficiency Scale.

3. Records and Plans of the physical structures and operation of the system to be complete, in convenient form, safely filed, in duplicate, indexed, and up to date.

Records or plans:	Points.
a. Slightly incomplete.	5
b. Moderately incomplete.	10
c. Very incomplete.	25

4. Emergency Crews shall either be on duty at all times or quickly available; an emergency wagon, preferably motor-driven, loaded with necessary tools, shall be provided. At least one responsible employee familiar with the system shall respond to fire alarms in mercantile districts, and to second alarms elsewhere.

Emergency provisions:	Points.
a. Fair.	5
b. Poor.	15

5. Alarms of Fire shall sound in some quarters of the department. Alarms shall sound in pumping stations of direct pumping systems; where pressures are raised to furnish direct hydrant streams, or pumps are started to furnish fire service, duplicate alarm circuits shall be provided as to fire stations; telephone service to pumping station shall be considered as 25 per cent. of total requirements. Lack of operating force on duty equivalent to deficient alarm service.

	Points.
Means of receiving fire alarms: Alarms not received by the department.	10

In direct pumping system use $\frac{1}{10}$ Deficiency Scale for deficiency at pumping station, or $\frac{1}{5}$ Deficiency Scale if pressures are raised for direct hose streams.

6. Adequacy, as regards Capacity, of Source of Supply and Supply Works, to deliver Required Supply to the District Considered. In this item there must be considered the normal ability of the source of supply, including impounding reservoirs, and of each part of the supply works to maintain maximum consumption demands and fire flow corresponding to the population as specified in the table hereinbefore given. Because of local conditions, a lesser or greater fire flow than called for by the population figures is sometimes deemed sufficient or necessary; in such cases the same fire flow shall be used in Items 8, 11, 16, and 21. In considering the source of supply, if shortage of supply is intermittent, apply deficiency under Item 7; if practically constant, as from wells, apply under Item 6. Under Supply Works, which includes intakes, suction lines, pumps, boilers, stacks, air compressors, filters (if not by-passed), and force or supply mains, storage shall be assumed as offsetting only deficiency in ability to deliver fire flow, and not deficiency in ability to meet consumption demands, except that where storage is large and records indicate no shortage in domestic consumption, it shall be assumed that no deficiency exists, if ten hours' fire flow could be obtained throughout this period for cities over 2 500 population, and five hours' fire flow for cities under this population. Filters may be assumed as capable of 25 per cent. overload capacity.

In considering the deficiency under this item, results obtained at fire flow tests in the most favorable location in the district shall be used as a basis in making calculations as to the probable deficiency under maximum consumption conditions, due allowance being made for any emergency supply. The extent of deficiency of each part of the supply works must be considered and the percentage of deficiency of the most serious used.

a. For average domestic consumption and fire flow: Use 2 times Deficiency Scale.

b. And add for maximum domestic consumption and fire flow: $\frac{1}{2}$ Deficiency Scale.

When direct hydrant streams are used by the fire department, and the engine capacity available (including the quantity from

high-pressure fire systems) is less than $\frac{2}{3}$ the fire flow obtainable at time of maximum consumption from the domestic system in the weakest part of the district at pressures permitting direct hydrant streams, apply a deficiency under sub-item *c*.; this deficiency to be based on the proportion of the total fire flow required available at the strongest point in the district.

c. For fire flow available at the strongest point in the district at pressures permitting direct hydrant streams: Use $1\frac{1}{2}$ times Deficiency Scale.

Deduct 10 per cent. of points of deficiency for each 10 per cent. of engine capacity available, this per cent. to be based on $\frac{2}{3}$ fire flow required.

7. Reliability of Source of Supply. The effect on adequacy must be considered for such items as frequency and duration of droughts, physical condition of intakes, danger from earthquakes, floods, forest fires, ice dams and other ice formations, silting-up or shifting of channels, absence of watchmen where needed, or injury by physical means. No item is to be considered which is covered by requirements hereinafter given.

Use 2 times Deficiency Scale in proportion to degree of unreliability, as given on page 13.

8. Reliability of Pumping Capacity on which supply is dependent, shall be on the following basis:

Pumping capacity must be such, with the two largest pumps out of service, as to maintain maximum consumption and fire flow at required pressure; for cities under 25 000 population, maximum consumption and $\frac{1}{2}$ fire flow, and for cities under 2 500 population, maximum consumption and $\frac{1}{4}$ fire flow.

Deficiency, when pumping capacity under conditions given below in *a* and *b* is less than maximum consumption, shall be considered as offset by storage when the difference between maximum consumption and the output of the pumps is equaled by $\frac{1}{5}$ the storage after deducting fire flow for ten hours; when pumping capacity is greater than maximum consumption, the excess capacity plus 2.4 times the storage shall be considered as offsetting deficiency if equal to the fire flow in million gallons a day.

In cases where both low-lift and high-lift pumps are provided and reliability of supply is dependent on each, they must be considered separately and the point of deficiency added. If, as in a system supplied by deep well pumps, the deficiency in adequacy of supply and pumps is equal, assume it as due to supply, and do not use required quantity as basis in this item.

Where capacity remaining, alone or in connection with storage, does not equal domestic consumption, the proportion available at desired pressure may be allowed; full credit will be given for all pumps capable of delivering against fire pressure.

a. Use Full Deficiency Scale for deficiency on basis of one pump out of service.

b. Add $\frac{1}{4}$ Deficiency Scale for deficiency on basis of two pumps out of service.

9. Boiler Capacity, with a reserve of one fourth the entire capacity, and in any case at least one boiler, must be sufficient to operate all machinery and the pumps required, as determined under Item 8, to maintain maximum consumption and fire flow, with allowance made for storage. In cases where both high- and low-lift pumping is used, the points of deficiency found under each condition must be added.

Normally, there must be sufficient boiler capacity, under at least $\frac{1}{2}$ required steam pressure, to deliver full requirements, in connection with storage, for a period of two hours.

With sufficient stack or forced draft capacity, an overload of 50 per cent. over the maker's rating may be used for fire tube boilers, and 100 per cent. for water tube.

a. Use $\frac{1}{2}$ Deficiency Scale for deficiency in boiler capacity.

b. Add $\frac{1}{4}$ Deficiency Scale for deficiency in boilers under steam.

10. Condition, Arrangement, and Reliability of Plant Equipment. The following forms and combinations of plant equipment, if of modern design and well constructed and installed, are assumed as approximately equal, advantages of each, if any, being in the order of their naming:

a. Centrifugal or reciprocating pumps driven by steam engines.

b. Centrifugal or reciprocating pumps driven by electric motor. Generating station must meet conditions of Items 7 to 15, inclusive, Item 8 to be generators instead of pumps, and deficiency applied.

c. Pumps operated by water power; must meet conditions of Item 7 and deficiency applied.

d. Centrifugal or reciprocating pumps operated by internal combustion engines approved for this service. Duplicate ignition parts must be on hand for each engine. Adequate provision must be made for starting engines cold at least six times in rapid succession.

All equipment must be of a design applicable to the service; service record in the plant under consideration and in similar plants shall be considered, and actual operating conditions observed. Pumps are to be free from knock, with low slip, and capable of operating at full speed. Boilers shall be well set, in good condition and with proper semi-annual inspection service; stacks shall be substantially installed. Electrical equipment for power shall be in accordance with National Electrical Code and not liable to injury by water spray. Water-power equipment must be accessible and properly safeguarded. Operating force shall be competent. Consider also arrangement of apparatus as to ease of repairs, etc.

On basis of capacity affected and degree of unreliability: Use Full Deficiency Scale.

Note. — A deficiency may apply under this item though there is no deficiency under Items 8, 9, and 11.

11. Fuel, and Accessories for the Transmission of Power. A minimum of five days' coal supply shall be provided; where long hauls, condition of roads, climatic conditions, or other causes, make a longer interruption of delivery possible, a greater storage shall be provided. Gas supply shall be from two independent sources, or from duplicate gas producer plant with a storage of at least twenty-four hours' gas supply. Oil supply shall be from underground storage of at least five days' capacity, with force feed to engine or boiler. Unreliability of gas or oil supply to boilers may be lessened by proper provisions for the use of coal.

Water for power shall equal at all times that necessary to meet maximum requirements (or other power provided to equalize deficiency) and shall have proper flood and ice control.

Steam piping (or gas or oil piping with internal combustion engines or to boilers) or electric transmission lines shall be so arranged that a failure in any line, or the renewal of a transformer or oil pump would not prevent maintaining, in connection with storage, maximum domestic consumption for two days and fire flow for ten hours; for cities under 25 000 population, maximum consumption for two days and $\frac{1}{2}$ fire flow for ten hours, and for cities under 2 500 population, maximum consumption for two days and $\frac{1}{4}$ fire flow for ten hours. Overhead electric lines introduce a degree of unreliability which may be in part offset by storage; consideration in connection with such lines shall be given to number and duration of wind, sleet, and snow storms, character of poles and wires, character of country traversed, effect of forest fires, and ease of and facilities for repairs; the use of the same transmission line from the transformer or switchboard by other plants introduces a hazard of short circuit or prior use of power and may be considered as the equivalent to the use of overhead lines in applying the schedule.

a. Adequacy and reliability of fuel:
   Use $\frac{1}{4}$ Deficiency Scale.

b. Electric lines, including transformers:
   Use $\frac{1}{4}$ Deficiency Scale.
   For overhead lines, add in proportion to unreliable service and installation, Full Deficiency Scale, and increase points of deficiency 1 per cent. for each mile length of overhead line on which normal service depends.

c. Steam, gas or oil piping:
   Use $\frac{1}{4}$ Deficiency Scale.

Note. — Where stations are dependent upon each other for operation, a cumulative charge shall be made for the condition at each. Item a may apply in addition to b and c. When deficiencies in both items b and c occur in or to the same station, or stations performing the same service, apply only for the greatest deficiency.

Pumping Station:

12, 13, 14, and 15. Pumping stations and other portions of the plant shall contain no combustible material in their construction; otherwise an automatic sprinkler equipment shall be provided; outside hydrants and hose, inside standpipes and small hose, and chemical extinguishers shall be provided. Public fire station, if within $\frac{3}{4}$ mile, shall be considered as giving about $\frac{1}{2}$ protection. If pumping station is not fireproof, the several sections, particularly any with high potential generating equipment, shall be separated by parapeted fire walls, and openings protected by standard fire doors or wire glass in metal frames. Station shall be protected against exposures. Electric wiring shall be in accordance with the National Electrical Code and all internal hazards safeguarded.

Note. — Under Items 12 to 15, inclusive: Where two or more stations are not dependent upon each other for operation, apply deficiency to the best station in the proportion of its capacity to the total required, and to the other stations in the proportion of capacity necessary to obtain remaining required supply. Where stations are dependent on each other for operation, apply deficiency to each. Deduct one tenth the points for each day's storage in reservoir in excess of ten hours' fire flow.

	Points.
12. Construction:	
a. Small amount of combustible material in roof structure.	10
Or,	
b. Small amount of combustible material in roof and floors.	15
Or,	
c. Considerable amount of combustible material in roof structure, floors and wainscoting and / or partitions.	25
Or,	
d. Largely or wholly frame: for each 25 per cent.	10

Note. — If sprinklered throughout, do not consider a, b, or c, and charge only $\frac{1}{2}$ of d.

	Points.
e. Combustible roof covering.	30
f. Sections not properly cut off.	10

Note. — The deficiency may include e and f in addition to any other one item.

13. Insufficient fire protection, other than sprinklers.

a. If 12 a or b applies.	5
b. If 12 c, d or e applies.	10

14. Hazards:

a. Low potential wiring defective.	5
Or,	
b. Low potential wiring hazardous.	10
c. High potential wiring defective.	10
Or,	
d. High potential wiring hazardous.	25
e. Heating by stove or gas.	5
f. General care, including storage of oils, poor.	5
Or,	
g. General care, including storage of oils, very poor.	10
h. High potential generating or transforming apparatus; if in non-fireproof building and not cut off by blank parapeted wall.	20

15. No protection:

a. To moderate exposures.	10
b. To serious exposures.	25

Note. — If 12 d or e apply, use double the points for 15 a and b.

16. Reliability of Supply Mains as Affecting Adequacy. Under this heading will be included any and all pipe lines or conduits on which supply to the distribution system is dependent; suction or gravity lines to pumping station, flow lines from reservoirs, force mains, etc., are included, and a system may have one or all of these as part of it. Under 6, the adequacy of these lines under normal conditions has been considered. Consideration must be as to greatest effect on maximum consumption and fire

flow at required pressure that a break could have; for cities under 25 000 population, maximum consumption and $\frac{1}{2}$ fire flow, and for cities under 2 500 population, maximum consumption and $\frac{1}{4}$ fire flow. In applying, all mains which deliver from a source of supply or of storage to the principal mercantile district must be considered. Aqueducts, of good design and of substantial construction, such as masonry or concreted steel, if so installed as not to be deficient under Item 17 following, shall be considered sufficiently dependable as not to require duplication, and no application will be made as to the effect of a possible break.

Under the assumption of the most serious single break, when capacity of mains from the source of supply is less than maximum consumption, deficiency shall be considered as offset by storage when the difference between maximum consumption and the capacity of the mains is equaled by $\frac{1}{5}$ the storage after deducting fire flow for ten hours, except as restricted by the capacity of the mains from the storage. If remaining mains and storage cannot deliver even maximum consumption, allow for only that amount available at required pressure.

When capacity of the mains from the source of supply is more than maximum consumption, the excess capacity plus 2.4 times the storage shall be considered as offsetting deficiency if equal to the fire flow in million gallons a day. The effect of a break in suction or discharge headers, lack of by-passing or poorly gated by-pass or arrangements at any reservoir, filter, etc., poorly arranged cross-connections, etc., must be considered; also features which would tend to cause or prevent an interruption of service, such as length of line, and two or more lines from the same or different sources or from storage.

Deficiency for each individual possible break must be considered, and charge made for the case giving the maximum total number of points, including the increase due to distance.

For maximum effect on domestic consumption and fire flow of any single break in any main, apply $\frac{1}{2}$ Deficiency Scale, and increase the points of deficiency by 1 per cent. for each 1 000 ft. of main in which a single break would produce this maximum effect.

For supply lines not under vacuum and entirely on private right of way, decrease the above total by 10 per cent. for each 10 lb. pressure less than 50 lb., for the maximum pressure carried on the lines.

17. Reliability of Installation of Supply Mains. Must be in good condition and reliable; cast-iron, wrought-iron, wood-stave, and masonry conduit have been found satisfactory in various places and under certain conditions; service records and general conditions must be considered. Mains shall be so laid as not to endanger each other, and their failure at stream crossings, railroad crossings, and other points where physical conditions are unsatisfactory shall be guarded against; they shall be cross-connected and gated about once a mile and be equipped with air-valves at the high points and blow-offs at the low points. The general arrangement of valves, specials, and connections at cross-overs, intersections, reservoirs, and discharge and suction headers must be considered, with the view to quickness in shutting down breaks and repairing valves.

Use $\frac{1}{2}$ Deficiency Scale in proportion to degree of unreliability.
Note. — If more than one main and conditions do not affect all, apply in proportion to the carrying capacity affected, and the degree of unreliability. A deficiency may apply under this item even though there is no deficiency under Item 16.

18. Arterial System. In connection with the supply mains, arteries and secondary feeders shall extend throughout the system. These feeders shall be of sufficient size, considering their length and the character of the sections served, to deliver fire flow necessary for the district, shall be frequently spaced (about every 3 000 ft.) and looped. Basis of deficiency applied to be the results of fire flow tests and general consideration of the arrangement.

	Points.
a. Fair.	**10**
b. Poor.	**20**
c. Very poor.	**50**

19. INSTALLATION. Mains of the arterial system shall not be laid across filled ground, and shall have special construction at railroad crossings and near bridge abutments, and shall be so gated that not more than $\frac{1}{4}$ mile within the distribution system will be affected by a break. All mains shall have sufficient cover to prevent freezing, with a minimum cover of 2 ft. to prevent injury from traffic.

	Points.
a. Slightly unreliable.	5
b. Moderately unreliable.	10
c. Seriously unreliable.	25

Note. — Consideration not to be given to conditions already covered by 17 above.

20, 21, 22, and 23. MINOR DISTRIBUTORS AND GRIDIRON SYSTEM. Six-inch is to be considered the minimum size satisfactory for hydrant supply in residential districts; to be closely gridironed with 6-in. cross-connecting mains at intervals not exceeding 600 ft.; or where initial pressures are high, a satisfactory gridiron may be obtained by a liberal per cent. of larger mains cross-connecting the 6-in. at greater intervals; in new construction, 8-in. should be used where dead ends and poor gridironing are likely to exist for some time, and 6-in. only where blocks are 600 ft. or less in length. In high-value districts, the minimum size is to be 8-in., with cross-connecting mains at distances as given above; 12-in. and larger mains to be on the principal streets and for all long lines not cross-connected at frequent intervals.

20. Effect of Small Mains in High-Value District Considered:

For deficiency in fire flow in the part of the district where the least supply is available, whether due to weakness in the system or low pressures: Use Full Deficiency Scale.

Per cent. of deficiency to be based on fire flow obtained at strongest point in district, except where this exceeds required fire flow, in which case the latter should be used as basis.

21. Small Mains in Distribution System:

For per cent. of 4-in. or smaller mains supplying hydrants: Use Full Deficiency Scale for cities over 10 000 population, and ½ Deficiency Scale for cities under 10 000 population.

Note.—Not to be considered where laid only to supply domestic consumption and hydrants are not directly supplied by them.

Reduce the points of deficiency 5 per cent. for each 10 lb. average normal static pressure above 20 lb. in cities depending on engine streams and 60 lb. in cities without engines or depending on hydrant streams.

Use as normal static pressures the fire pressures regularly carried on second alarms.

22. Dead Ends. — For per cent. of 6-in. and 4-in. pipe, dead-ended, on basis of total length of pipe in the distribution system, to include dead ends at service limits: Use Full Deficiency Scale.

Reduce the points of deficiency 5 per cent. for each 10 lb. average normal static pressure above 20 lb. in cities depending on engine streams and 60 lb. in cities without engines or depending on hydrant streams. Use as normal static pressures the fire pressures regularly carried on second alarms.

23. Gridiron (average condition in closely built residential sections): 6-in. or smaller mains on long side of block, with 8-in. or larger cross-connections:

	Points.
a. At intervals of 600 to 900 ft.	15
b. ,, ,, ,, 901 ,, 1 200 ,,	30
c. ,, ,, ,, 1 201 ,, 1 500 ,,	45
d. ,, ,, ,, 1 501 ,, 1 800 ,,	65
e. ,, ,, ,, 1 801 ,, 2 100 ,,	85
f. ,, ,, ,, 2 101 ,, 2 400 ,,	100
g. ,, ,, ,, 2 401 ,, 3 000 ,,	115

If cross-connections are 6-in. or smaller, increase points of deficiency by 50 per cent.

Reduce points of deficiency 10 points for each 10 lb. average normal static pressure above 20 lb. in cities depending on engine streams and 60 lb. in cities without engines or depending on hydrant streams. Use as normal static pressures the fire pressures regularly carried on second alarms.

Do not apply Item 23 where deficiency under Item 22 exceeds 75 per cent.

24. PIPE. In distribution system, pipe must be of satisfactory quality and properly tested for soundness and tightness of joints. The use of cast-iron pipe under pressures more than double that specified for the class is considered as introducing an unreliable feature, particularly where pressures are raised for fires; tests before backfilling and service records of several years' duration may be assumed as offsetting in part this defect.

Use ½ Deficiency Scale for cement-lined pipe, and ½ Deficiency Scale for wooden or metal pipe in unreliable condition.

25. ELECTROLYSIS conditions are to be studied and methods of prevention applied.

	Points.
For conditions favorable to electrolytic action.	10

Note.—If there is evidence of recent serious electrolytic action, double the above points.

26. GATE VALVES. The distribution system shall be equipped with a sufficient number, so located that no single case of accident, breakage or repair to the pipe system, exclusive of arteries, will necessitate the shutting from service a length of pipe greater than 500 ft. in high-value districts, or greater than 800 ft. in other sections, and will not result in shutting down an artery.

	Points.
Spacing in high-value districts:	
a. Average 600 to 900 ft.	10
b. Average over 900 ft.	25
Spacing in residential districts:	
c. Average 900 to 1 500 ft.	5
d. Average over 1 500 ft.	15

27. Inspection and Condition of Valves. All valves shall be inspected yearly and large valves more frequently, and be kept in good condition; the presence of some valves operating in opposite direction is to be considered the equivalent of unsatisfactory condition, ranging from fair to poor, depending on the number and importance.

	Points.
Gate valves not inspected regularly or in poor condition.	20

28 and 29. Hydrant Distribution. Shall be sufficient to give an average area served, in proportion to the fire flow, as given below; where no engines are in service, direct hydrant stream spacing to be required. Four- or 6-way hydrants with independent gates on outlets may be assumed as two hydrants in figuring area served.

Fire Flow Required, Gal. per Minute.	Average Area per Hydrant, Sq. Ft.
ENGINE STREAMS (150 lb.).	
1 000	120 000
2 000	110 000
3 000	100 000
4 000	90 000
5 000	85 000
6 000	80 000
7 000	70 000
8 000	60 000
9 000	55 000
10 000	48 000
11 000	43 000
12 000	40 000
DIRECT HYDRANT STREAMS (75 lb.).	
1 000	100 000
1 500	90 000
2 000	85 000
2 500	78 000
3 000	70 000
4 000	55 000
5 000 and over	40 000

	Points.
28. Area served in high-value districts in excess of requirements.	
For each 10 000 sq. ft.	10

The area of a high-value district is to be bounded by a line midway between the nearest inside and nearest outside hydrant, but not exceeding 300 ft. from the inside hydrant. If at direct hydrant streams, fire flow in weakest part of the district exceeds the engine capacity available, apply on direct hydrant stream basis.

29. Area served in the residential district in excess of requirements.

	Points.
For each 10 000 sq. ft. that area in which block fronts have $\frac{1}{3}$ the lots built upon, but to exclude the high-value district.	3

The maximum charge for no hydrants in the residential district is to be 400 points. If on first alarm in residential district, an average of one half the companies are engines, use engine basis.

30. Condition of Hydrants. Hydrants shall be inspected in the spring and fall of each year, after use at fires during freezing weather and daily in high-value districts during protracted periods of severe cold.

	Points.
a. Not inspected, or in only fair condition.	10
b. In poor condition.	20

31 and 32. Size and Installation of Hydrants. Hydrants shall be able to deliver 600 gal. per minute, with a loss of not more than $2\frac{1}{2}$ lb. in the hydrant and a total loss of not more than 5 lb. between the street main and outlet; they shall not have less than two $2\frac{1}{2}$-in. outlets and also a steamer connection where steamer service is necessary. Street connection should be not less than 6 in. in diameter; connections to street main shall be gated. Hose threads on outlets should conform to the National Standard. Flush hydrants, requiring chucks to be screwed on, are considered undesirable, especially in sections of the country subject to heavy snowstorms, because of delay in getting in operation.

31. Hydrants too small; to include all with 4-in. connection to main, or those having a friction loss greater than noted above, except those hydrants with steamer outlet in cities using engines and with static pressure of at least 60 lb.; also to include all with single 2½-in. outlet, and all flush hydrants requiring chuck to be screwed on or where covers are liable to be covered by heavy snow fall, except that flush hydrants, with an adequate number of chucks provided having more than one 2½-in. outlet, are to be considered on basis of ½ deficient. If in high-value district considered there are more hydrants than are required for proper spacing, and the small hydrants are not generally used by the fire department, use in determining the deficiency only the number of small hydrants required to make up the total number necessary for proper distribution; i. e., do not charge for the surplus small hydrants.

a. Use ⅕ Deficiency Scale for those in high-value districts.

b. And add $\frac{1}{10}$ Deficiency Scale for those elsewhere.

	Points.
32. Hydrant connections to street main not gated: Each 10 per cent.	1

If 26 b or d apply, use double the points.

If no deficiency under 26, do not apply 32, unless hydrants on main arteries are not gated, in which case use a total of 10 points.

Discussion.

Mr. C. W. Sherman. One thing already in our Journal is so pertinent in this connection that I cannot refrain from quoting it. Mr. Frank A. Barbour, in his paper entitled, "Insurance Rates and the Water Service," * referred to three or four cities where he had recently, at that time, assisted in radically improving the water-works system. He put in this statement: "It is safe to say that in none of these cases was there any attempt

* Journal N. E. W. W. A., xxii. 322.

to estimate the value of the improvements in reducing the fire hazard on any definite basis derived by experience and made applicable by records of fire losses in relation to the character of the water service. It would seem, however, that the time must soon arrive when such logical proportioning of rates to the factors comprising fire hazards will be possible."

It has been eight years since that was presented, so perhaps it has not come quite so soon as Mr. Barbour thought it might logically follow. Nevertheless, in those cases it was only by strenuous exertion, and usually after the improvements had been made, that any improvement in the insurance rate was obtained, but in the cases quoted by Mr. Barbour insurance deductions were finally obtained, which in large measure compensated for the cost of the improvements actually made.

Mr. George W. Booth.* I want to express to you at the start our appreciation of your coöperation and to say that we shall be glad to have, from any member of the Association, his comments on any part of the schedule. We hope within the next month to present the schedule to the National Board Committee having the matter in charge, with the idea of issuing a revised edition which we can recommend for adoption by insurance organizations generally.

I would like to mention also the fact that the New England Insurance Exchange, which operates in this territory, has for the past year or so been applying a schedule which, although it goes into less detail than the National Board schedule and considers only a few of the principal fire protection features, does undoubtedly give very much more consistent results than were obtained previously. This schedule and classification have as yet been applied only to dwelling-house rates.

Concerning the questions raised by your committee: First, that of connections to distribution system, I feel that a sharp distinction should be drawn between connections to automatic sprinkler systems and those for manufacturing purposes, elevators, standpipes, etc. The automatic sprinkler system is one of the greatest of fire preventers, and to be effective, we are agreed that the connection should be of adequate size. What this size

* Chief Engineer National Board of Fire Underwriters, New York.

should be is a question that has been often debated in this Association, and I will not attempt to discuss it here. Personally, I believe that the proper way to attack the problem is to safeguard these connections in every possible way, so that flow from them may be controlled when necessary, rather than to insist on a limiting size which will be in some cases of doubtful adequacy; to install a size smaller seems to me only a partial and unsatisfactory solution of the problem. I am ready to admit that there is in some quarters a tendency to demand connections larger than there is any reason or necessity for, but I hope that it will be possible in the near future to secure recognition for reasonable standards. In this connection, I want to draw your attention to the likeness between the connection to an automatic sprinkler system and a fire hydrant; you will agree that it would be poor policy to provide too small a hydrant branch, with the idea of limiting waste when a hydrant, especially one opening with the pressure, may be broken off, as they not infrequently are; likewise, it very frequently happens during large fires or conflagrations that the rapid spread of fire compels the abandonment of a hydrant left open and wasting large quantities of water. On the other hand, there have been comparatively few cases where the breaking of connections to automatic sprinkler systems, as distinct from other large connections into buildings, has resulted in a serious waste of water.

As to the question of recognition of the 4-in. hydrant, it is not out of the question, nor even difficult to design a hydrant with 4-in. foot valve which will meet the capacity requirements of the schedule; Mr. McInnes's experience in the design of a hydrant for the Boston high pressure system shows that to be a fact. And, even though none of the commercial 4-in. hydrants meet these requirements, some of them come pretty near it. I think we can dispose of the problem as presented by means of a provision we contemplate making, to exclude from consideration in the schedule, outlying sections detached from the district which is being classified, or which are so remote from it as not to offer any exposure hazard.

The gravity cities, as a rule, will grade better than the direct-pumping cities, because there are fewer items to be considered,

fewer chances of interruption of service. As a rule, your New England cities, being largely of the gravity type, show up better than those in the Middle West, where it is necessary to depend on direct pumpage.

Mr. R. J. Thomas.* I should like to say a word in regard to the importance of this question in our city. Probably it is the case of most of the cities of Massachusetts. Considerable money has been spent in the last five or ten years in improving the water-works system, with a view of extinguishing fires. Larger mains have been laid, more hydrants have been installed, and considerable money expended in order to put the city in a position to protect itself from conflagration or large fires.

In the city of Lowell, within the last eight years, we have expended, on the recommendation of the National Board of Underwriters, about $300 000. I presume other cities have gone along in the same line, towards carrying out the recommendations of the Board; with the result that the insurance rates have not decreased, but have increased. I think in every city in Massachusetts the insurance rates have increased quite considerably — I understand about thirty-three per cent. on some classes of property.

Now, the trouble is not with the National Board of Underwriters, nor with the cities making the improvements, but it is with the insurance organizations, the men who have the control of fixing the rates; the men that are doing the financing; the men who look upon the insurance companies as a business.

We approach the different rating committees, who have meetings at Boston at the New England Exchange, and it is difficult to arrive at an understanding between the different cities and the insurance committees. They take the financial view of it, the insurance view, while the cities, of course, are also looking for a decrease in insurance rates, as they reasonably should expect to do, considering the expense that they have been to in making improvements.

The National Board of Underwriters, as I view it, is just the medium for the water-works people to look to for bringing about

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* Superintendent of Water Works, Lowell, Mass.

a better understanding with the insurance organizations. The National Board of Underwriters, or their engineers, at least, are water-works men. They have water-works ideas, and look at the matter from our standpoint, and will be a great help to the water department, or the fire department, and the city interests in general who are making these improvements. The National Board will help us in getting a reduction commensurate with the improvements that we make. Therefore this new grading schedule ought to be something we should adopt; something we should favor, and something we should support in every way possible.

At the present time, as I understand it, they have a schedule that applies mostly to residential property, classified A, B, C, and so forth. There are very few cities in New England — and I believe but two or three in Massachusetts — that come under the classification of Class A. Most of them are in Class B. In our efforts in Lowell to be placed in the Class A rating, we found it was almost impossible for us to put the city in shape to come under that classification, under the present schedule, but we hope under this new schedule, under this new grading, to have a good deal better standing. We expect to be credited with the amount of money spent in making these improvements. Of course, we are in just the same position as every other city and every other water-works department in New England. They all undoubtedly want to get credit for the money expended; expended upon the recommendation of the Board of Underwriters, and by supporting the National Board is the only way I know of that we can reach the insurance interest and get it.

Undoubtedly, the insurance organizations will be guided by this schedule, and by their advisers, the National Board and their engineers, and I hope all the members will look into this subject, and give it considerable thought, because the insurance rates are a matter of great importance to every community. Of course, the higher the insurance rates, the more dissatisfaction you will have among your people over the money expended. Aside from any expectation of reduction of the insurance rates, every water department superintendent and every public official wants, in so far as the city is able, to protect the city against a conflagration such as occurred in Salem and in Chelsea. By working along

these lines, and under the advice of the National Board, we will be achieving that purpose.

It seems to me that the schedule as laid down by the National Board is substantially as good as can be devised by engineers, who have the knowledge of not only the water works but the fire department and the features that go to make up the grading basis.

I hope that some of the members who have different views may give expression to them this morning, so that we can have something to work on.

Mr. Fuller. I should like to ask Mr. Booth if the matter of sprinkling schoolhouses is in any way compulsory, and if it is not, why it should not be.

Mr. Booth. So far as this schedule is concerned, the compulsory sprinkling of any class of buildings has not been considered. That is to be taken care of by state law, or, as in the case of Boston and vicinity, the fire prevention commissioner. It is not possible by any insurance regulations to compel the sprinkling of anything. There are cities that do have ordinances regarding the sprinkling of basements, for instance. But I think there is no state law.

One thought that Mr. Thomas suggested, and that is the difficulty in arriving at an understanding in regard to reasonable rates of insurance. One reason why that has not been possible is because there have not been any classified records of fire losses, to enable either the fire insurance companies or anybody else to say what is a fair rate. About a year ago, the National Board established a new bureau, the Actuarial Bureau, which is intended to do just that, and beginning with the 1st of January, 1915, those records have been kept. For the first year it was experimental in a way, because it was a big job, and nobody knew just what they wanted or how to go about it, so the first year records will not be so valuable as they ought to be from now on.

Those records are classified by states; that is, the fire loss in each state, and for each of about two hundred classes of property and occupancy. When the records are completed, you will be able to tell, for the year 1916, what the fire loss in the state of Massachusetts was, in either one of two or three different kinds of construction, and many kinds of occupation. It is a big con-

tract, and had to be gone about very slowly. Whether that can be used in all its refinements as a basis for making rates, in my opinion it will certainly be a very large factor in determining what the proper rate is.

Mr. W. C. Hawley.* This is an age of efficiency, and we must expect our plants to be efficient, and, in addition, furnish first-class fire protection.

As I look back to the discussions which we have had in this Association, years ago, and think of the wide divergence of views of the insurance men and the water-works men, I am glad to see that we have come so near together. That was brought out particularly at the June meeting of the American Water Works Association, — the matter of size of pipe and connections for fire protection. The insurance men have come practically to the views of the water-works men, whereas a few years ago they wanted service much larger than we were willing to grant.

I think this proposed plan is a most excellent one, and if it will only filter down from the heads of the insurance companies to the people that we come in contact with, out on the firing line, as it probably will in time, it certainly will be a fine thing.

In my own town, about two years ago, we found that the commercial risks were paying a penalty, I have forgotten how many cents, for lack of pressure, although in the business district and in a large part of the residential district of our town we had a pressure of from 125 to 175 lbs. per square inch. We were also paying a penalty for lack of required-sized mains, and when our board of trade took that matter up with the County Board of Underwriters we were informed that, because there were some 4-in. mains in our city, the penalty would stand. It made no difference, although I offered to demonstrate that we could throw more than twice the number of effective fire streams, nearly three times the number of effective fire streams, that the secretary of the board thought there should be available. That made no difference, that penalty still stands.

I hope that this work which is in progress now will ultimately reach our section of the country, and help us out in the proper adjustment of insurance rates.

* Chief Engineer, Pennsylvania Water Co., Wilkinsburg, Pa.

Mr. R. C. P. Coggeshall.* Our situation in New Bedford is different from most any other city. Every drop of water that is used by our industries has to be supplied by the water department. There is no secondary supply, such as there is at Lawrence, Fall River, Holyoke, and Manchester. It all has to come from the city of New Bedford. The consequence is, that at times — especially Monday morning, for instance — the draft upon our reserve is upwards of 20 000 000 gal., or at that rate. The result is that we have large mains, so as to equalize the pressure in all parts of the town, and that has been an incentive to getting a pretty reliable supply there. We have made it a point to remove all the small mains. The 4-in. are generally replaced with an 8-in. size. The result has been that we have pretty fair fire protection there now; but, while the water works and water department have done their duty in the city of New Bedford, the building laws are most terrifically lax, and it seems as if in the same proportion that we have made the water supply more reliable, the fire hazard has increased. You need none of you be surprised, some day, to have a huge conflagration, when the conditions come right; and, with the admirable supply, the mills are more exposed to a fire hazard from outside than they are from inside. Under a southwest wind, blowing over the city and going against those mills, there may be a terrible conflagration.

I think, sometimes, we may look to the building laws, and to stricter building laws, to better conditions. The erection of these three deckers in huge blocks, in the vicinity of the mills, is perhaps one reason why we have not reduced the insurance rates there.

Perhaps Mr. Booth can tell us something about that, whether or no the water departments have not done their duty, where the city has been very lax in administering the building laws.

Mr. Booth. It is perfectly true, as Mr. Coggeshall intimated, that the worst feature, in almost all cities we know of, now is the building condition. You can provide, as he has in New Bedford, a perfectly good water supply, and the city can provide, as it has in New Bedford, a better than normal fire department, and you have still got the conflagration hazard there; and it is a peculiar

* Superintendent Water Works, New Bedford, Mass.

thing that it is a great deal more difficult to get a city to establish a good building code and enforce it than it is to get them to spend money, especially in the fire department, as it appears. Perhaps you can guess for yourselves why that may be, in your own individual city, but it is true. It is a good deal more difficult to get them to pass reasonably good laws on building construction and enforce them than to get them to spend money for something that looks pretty, and makes a good show.

The weight to be given, in the schedule, to building laws has been debated quite considerably. On one side, some men would say there should be no weight given to building laws at all; it should not be considered in the schedule, because it will be given weight in its results when they are attained; that is, when you improve your building construction, you naturally get the benefit both in the schedule rating and in your individual building rating, but that item was left to encourage the adoption of good building laws, even though they might not result immediately or for some time in any material betterment of actual conditions.

One reason why we could not give more weight in the schedule to actual building conditions, as covered by structural conditions, — the last part of the schedule which you have not had printed here, — was that they would overbalance the features of protection, and, besides that, and particularly, the poor features of the individual building are penalized in the building rate itself. But the weight that is given to building construction in this schedule refers only to what we call the general conflagration hazard; that is, the effect on conditions in the district as a whole of the poor construction of any individual building or block.

Mr. H. V. Macksey.* In considering the report of this committee, I hope the members will remember that it really is a progress report; that we are only making progress along the lines that we have started on, and the underwriters are merely making progress. They have not yet reached a point where they are prepared to say, "This is the thing that is going to last." They have not yet reached a point where all the underwriters in the various sections of the country will place the valuation on fire protection, building hazard, all that sort of thing, but they are

* Superintendent of Public Works, Woburn, Mass.

trying to reach something that will be reasonable and equitable, and that will finally guide those who make the rates for fire protection in various cities.

While a very short time ago, when the matter was first projected in this Association, I believed that it would be useless for us to confer with them or attempt to assist them, I have since changed my mind, because I find that the representatives of the National Board, not only in this particular case but in others, are working on the proper lines. They are reasonable men, and trying to get assistance from us, and not trying, as some of the little fellows in the underwriting business, to browbeat us, to get the particular things that please them, from time to time. So we have worked along with the representatives of the National Board, and have agreed with them on many things, disagreed with them on a few, and there are others that just now we don't know what we should properly say.

Take the matter of the building hazard, which has just been under discussion. It is very plain that the building laws should have greater value than they are given, provided you could change them to-day and enforce them to-day, and make them effective on buildings already erected. Any change which you make in the building law of to-day will not affect buildings now constructed; and the buildings now constructed, I suppose, will last on an average of forty to fifty years. So that any small difference in the penalty charged against the city on account of building laws would have very little immediate effect, and even a large one would not have great effect.

In talking on the various items in the water department, the committee did not agree with the underwriters on a few points, and I think the principal ones were the penalizing of a 4-in. valve hydrant. A majority of the committee is strongly convinced that that hydrant should not be penalized, and that the matter of a slight reduction in pressure of the hydrant is of very little importance in a very great part of the field in which the hydrants are used; that while it may be valuable in crowded portions of large cities, in the suburban and country districts throughout the country it is of very little importance whether you have a 4-in. or a 5-in. valve hydrant. So many hydrants are taken off long

lines of 6-in. pipe, and so many fires are small affairs, attended by only one piece of apparatus, that, to our minds, it is fair to say that the 4-in. valve hydrant is perfectly efficient for the work we want it to do.

The argument has been made that the 4-in. valve hydrant can be made so there will be less loss by friction. That is probably true, but it would be well for us to take that up with the manufacturers of hydrants, but I don't think we should try to club them into line by penalizing them in that way.

There was another matter that some members of the committee thought was important, and that was that the underwriters should take a little of their own medicine; that they should penalize the demand for an over-large fire supply, or for very small main supply, but they have not quite seen that yet; but I think when they consider the great problem as a whole, rather than little portions of it, they will find that of importance.

I do not think it benefits the underwriters, any more than it does the city or taxpayers of any city, to have a factory which is willing to put in considerable money for a large sprinkler plant, designed by the experts of the underwriters so that they will be perfectly protected — I don't think it is of advantage to the city as a whole, nor the underwriters as a whole, to do that at the expense of the neighbors along the line. You can so arrange your water service that you can only protect one building, and leave all the others in the neighborhood crippled, and that is what the sprinkler men are liable to do, and they do it at the request and the demand of the underwriters' agent, and he puts on the penalty right away, because, if the city refuses to give the water service he demands, he penalizes the building right away, and shoots the insurance rate up.

So we are convinced that matter should have more attention; but the general idea of this grading scheme, we believe, is good. While in some cities we may get the bad end of it, and our water department get a very severe criticism, the man who does good work and has behind him good men, and means to put up a good water department, will get credit. That is all any of us ask. If we are unfortunate enough, through lack of means, or lack of ability, to be doing poor work, we must take our medicine. If

we are fortunate enough to have the ability and the means to do good work, we naturally want the credit. That is what we will get through this grading scheme when it is completely worked out and accepted by the underwriters' agents as a whole through out the country.

Mr. R. W. Wigmore.* I feel that this grading scheme is a move in the right direction. I know at the present time the National Board of Fire Underwriters have been doing this very work in St. John. While the city of St. John a few years ago expended a large amount of money on the extension of their water system, they have got very little return from it from an insurance standpoint. I believe in St. John to-day we are in a very good position, from a water-works standpoint. We have a very large number of three deckers, which is a very great hazard. We have no very good laws in connection with the electric wiring of buildings, and, on account of that, the insurance rates to-day in St. John are perhaps not any higher than they should be, looking at it from the building standpoint and from the wiring of the buildings. No insurance rates are reduced. They admit that our water department is in a fairly good position, but yet the insurance rates have remained the same for a number of years, — and in fact to-day there is talk of increasing them.

Now, from the standpoint of laying larger mains for sprinkler systems, we have endeavored during a number of years to limit the size of mains running in for sprinkler systems and supplies to 4 in., but there has been a demand during the last few years to increase that to 6, and, in fact, in one case this year they were asking for 8-in.

We have discouraged that, although in a few cases we have allowed the 6-in. To overcome that, and to make it safer, we insist that a regulating valve in the standpipe shall be placed on the curb, just in the same line that the hydrant is placed. The hydrant man of the department responds to all alarms. He has a team at his disposal; he gets on the scene of the fire as soon as the fire department. His first duty is to look after the fire hydrant, to see that everything is in good shape. After that, he watches the progress of the fire; if it is in a building where sprink-

* Water Commissioner, St. John, N. B.

lers have been installed, just as soon as he sees that the sprinklers are practically out of business, or of no more use, he goes to the regulating valve on the curb and shuts off the sprinkler system from the building. That is of some use. Some might say, "Well, the walls might fall." We don't let it get that far until the walls fall and prevent him from getting at his regulating valve.

I think there is one thing that the National Board of Fire Underwriters should try and discourage. That is, they should insist that no supply lines larger than 6 in. should be allowed in the sprinkler system.

THE APPLICATION OF COAGULANT INTERMITTENTLY IN EXCESS AMOUNTS AT SPRINGFIELD, MASS.

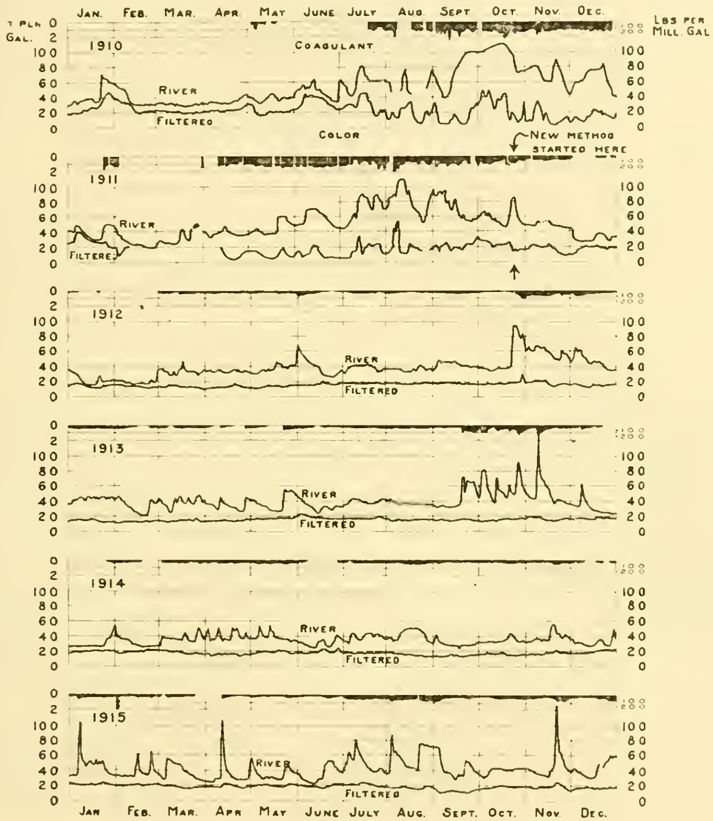
BY ELBERT E. LOCHRIDGE, CHIEF ENGINEER, SPRINGFIELD WATER WORKS.

[*Read September 13, 1916.*]

Coagulation by sulphate of alumina prior to slow sand filtration has been the practice at the West Parish Filter plant of Springfield, Mass., since its construction. Records are now available covering six full years. During the last four years of this time the method of application has been so altered that materially reduced amounts of coagulant are necessary, although at all times it has been possible to produce satisfactory water. This method has been the application of over-doses of sulphate of alumina to the water intermittently. The filters, six in number, are of the slow sand type and of one-half acre area each. The water of Little River as it comes to the filters is that of a mountain stream usually clear, of low alkalinity, but with a varying color, which with the rise of the stream may increase several fold within a few hours. The color in the river water may be low enough for use without any reduction for a long period of time, when suddenly a rise in the stream will cause a large increase of color which makes the water objectionable for use.

A chart is presented with this paper (Fig. 1) on which are two lines, the upper of which represents the color of the river water day by day, and the lower the color of the filtered water at the same time. These are plottings of daily results. The amount of sulphate of alumina in terms of both grains per gallon and pounds per million gallons is plotted above the color lines in such manner that the amount applied each day may be readily seen. This chart gives the comparison of the two-year period of 1910 and 1911, during which time coagulant was applied in the usual manner, with the years 1912, 1913, 1914, and 1915, in which the method to be described was used. The records for the six years are plotted in such manner that seasonal comparisons are also possible.

It is a well-known principle that it is necessary to apply enough sulphate of alumina to secure a complete reaction if the coagulant is to be of value in quickly clarifying the water. If, for example,



WEST PARISH FILTERS
SPRINGFIELD MASS
COAGULANT-GRAINS PER GALLON-POUNDS PER MILLION GALLONS
COLOR-RIVER AND FILTERED WATER

FIG. 1.

on a certain day one grain of sulphate of alumina per gallon is necessary to secure a complete precipitation or reaction and decisive reduction of color, nine tenths of a grain will not secure nine tenths or even five tenths of the same result. It is nec-

essary to apply the coagulant at least in the amount or rate necessary for this reaction point. It is, therefore, necessary to determine each day the amount of sulphate of alumina which is necessary to secure this clean-cut reaction. In 1910 and 1911 the amount thus determined as the least amount which would bring good results was the amount of sulphate of alumina applied that day. In the method adopted in October, 1911, and carried through all the subsequent records, this critical amount was as carefully determined, but a different use was made of the information.

A brief description of the general conditions and arrangement of the plant will help in the understanding of this process at this point. The Little River at the point of diversion has a catchment area of forty-eight square miles. Its elevation at this point is 496 ft. above sea level, and with steep slopes the ground rises to an elevation of from 1 500 to 1 700 ft. at the highest points of the watershed The surface of the storage reservoir on Borden Brook is 1 070 ft. above sea level, and 1 000 ft. above Main Street in Springfield. The water is diverted from the stream in a deep and narrow gorge, and sent through a mile of tunnel to a sedimentation basin 8 acres in area with a capacity of 40 million gallons, or between three and four days' supply. From this small reservoir the water is drawn to the filters. The water from the tunnel is carried by a concrete conduit to an arm at the greatest distance from the outlet. There are no baffles or other artificial obstructions in this reservoir. The coagulant is applied in solution to the water in transit in the concrete conduit at a point which causes it to travel with the current 540 ft., permitting some mixing before its submerged delivery into the basin. Water is constantly flowing from the river to this basin through the conduit and is drawn uniformly from this basin to the filters.

The determination of the amount of aluminum sulphate necessary for complete reaction is made in a series of two-gallon bottles from fifteen to twenty in number, which are filled each day with the river water. To these are added, in uniformly varying increments, definite amounts of sulphate of alumina. For example, to the first bottle enough is added to give the effect of the rate of 50 pounds per million gallons; to the next, 60 pounds; to the next,

70 pounds, and so on by ten pounds per million gallon increments to 270 pounds. Within a few hours all of the bottles with amounts of coagulant in excess of the "reaction point" will indicate complete color removal, and the precipitation of foreign matter will be complete, while all bottles containing less coagulant than this amount will be in a cloudy or murky condition, indicating incomplete reaction. The determination is made in this manner each day, permitting a study of the effects of the rise and fall of the stream, the effect of storms, melting snows, etc. This information is also of great value at times of sudden changes, when there is insufficient time to make the determination. The amount necessary is dependent on a number of different conditions. With waters of the same alkalinity there may be quite a marked difference in the amount necessary for reaction, varying with river conditions. It is not entirely dependent on the amount of color, as with the same color to be reduced it varies on different days. The amount of coagulant actually applied to the water is always a little in excess of the reaction point determined, and during the period of application this is kept as nearly constant as possible.

With the amount or rate of coagulant application per hour thus known, it is still necessary to determine the number of hours per day during which it shall be added. Throughout most of the year, from four to six hours per day is sufficient, but at a time of flood, resulting in a very material increase in color, this period may be lengthened to twelve hours, or 50 per cent. of the time.

Generally speaking, the standard set for filtered water is that of no coagulation if the color does not exceed 25. Before the filtered water reaches this figure, coagulant is resorted to, and during such application the color is to be kept at 20 or below. By referring to the accompanying diagram it will be seen that, since the adoption of this method, it has been possible to make the line of color in the filtered water substantially straight or uniform throughout the year; the consumer thus becomes accustomed to a water of low and definite color and never sees water of high color at any time. Under the old method of constant coagulant use, it was found impossible, especially at times of low alkalinity or sudden changes, to add sufficient sulphate of alumina to reduce the water to a satisfactory color at all times. The addition of

soda ash or lime was necessary for restoring alkalinity at such times. This is entirely unnecessary with the intermittent application, as but a small portion of the alkalinity is used in the formation of the floc. The first coagulation in the conduit and basin results in a water of substantially zero color, with at least a theoretically slightly acidic reaction. This treated portion of the water, which has entered the basin chemically active, with the precipitate or floc forming rapidly, is then followed by untreated water in a quantity, because of the longer period of time, in excess of the treated water. The thorough mixing of this raw water with the treated water is brought about at the outlet of the submerged conduit as it displaces the basin water at this point. The second reaction begins at once and is carried to completion with a restoration of alkalinity to the entire supply, this action probably being consummated during the period which elapses before the next application of coagulated water. The floc of the treated water has not had an opportunity to settle when the raw water is admitted, and readily furnishes a base about which the additional precipitation resulting from this secondary reaction forms, and serves to carry down color, sediment, and bacteria mechanically, as well as through the chemical reaction which is taking place in every part of the untreated water as it mixes with the overdosed water. The resultant reduction of color is, therefore, due to the effect of dilution of the higher colored water with water of no color; to the second reaction, which is, in reality, the completion of a reaction started under favorable conditions of overdosing, and which reaction chemically is always complete, as the excess of the applied coagulant is taken up by the alkalinity of the untreated water, resulting in the completion of the mass reaction; and also to the mixing of the floc of the fully treated portion with the mass of the entire day's water supply, before it has the opportunity to settle. The precipitate thus formed in a large part settles before it is carried to the filters.

The sedimentation basin was drawn off and cleaned after five years' operation of the filtration plant, and it was found that large masses of precipitated organic matter and aluminum hydrate had settled in the upper portions of the basin. This deposit covered the entire basin, varying from three to four feet in depth

near the inlet to a few inches in proportion to the distance from the point of entry to the basin of the raw water.

The average length of filter runs during the four years described in this paper of the use of this process were as follows:

Year.	Filter Runs after Scraping.			Filter Runs after Raking.		
	Number.	Average in Millions of Gallons per ½-acre Bed.	Maximum Runs in Millions of Gallons.	Number.	Average in Millions of Gallons per ½-acre Bed.	Maximum Runs in Millions of Gallons.
1912	22	76	90	26	76	84
1913	22	95	115	23	79	91
1914	26	85	152	24	77	157
1915	29	89	229	21	42	104

In conclusion, it may be said that the use of intermittent coagulation results in a saving in expense, uniform results of satisfactory quality, coagulation without exhausting alkalinities in soft waters, and coagulation without excessive overloading of the precipitated hydrate on the filter beds.

SOME ADVANTAGES OF A CLASSIFIED CASH-BOOK.

BY ALBERT L. SAWYER, WATER REGISTRAR, HAVERHILL, MASS.

[*Read September 15, 1916.*]

When I was asked to prepare a short paper on some branch of water-works accounting, I accepted with alacrity, but only from a grave sense of duty towards my fellow registrars and treasurers, as I felt that we had too long permitted our light to be hidden under the proverbial bushel. Looking over the programs of the meetings of the Association, I find very little space taken up by the office section, and yet we are really quite an important part of the organization of a modern water-works system.

The superintendents, engineers, and other experts map out the campaign like generals of an army, and we see the result of their plans in the shape of extensive works, reservoirs, and filtration plants; most of the credit for the success of the plant goes to them, and justly so; but the poor registrar, like the man behind the gun, has his work to do to make the victory possible in collecting the bills and seeing that the sinews of war are at hand, to say nothing of the exciting life that he leads getting the complaints over the telephone, excusing the acts of omission and commission of the superintendent, and acting as a general buffer between the operating department and the public.

It therefore seems that in all fairness we ought to be allowed occasionally to tell our problems and troubles and take counsel together in an endeavor to obtain the best results from our labors. I think that each office has its own peculiar conditions and methods, and, as I do not know the system that any of my colleagues are using, I may be offering nothing of value or that is not already known to you. What I propose doing, then, is to state briefly my own case; the conditions as I found them, and an outline of the methods which I have found practicable and workable, with special reference to the use of a classified cash-book. No matter how good we think our own system is, we may each of us get some new ideas from a discussion of the papers to be presented.

Our present municipal slogan is, " Hitch your heart to Haver-

hill," and all loyal citizens — either as members of our Chamber of Commerce, the Rotary Club, or as plain everyday citizens — are bound to announce that they represent a beautiful and rapidly growing city of 50 000, situated on both sides of the Merrimack River, covering a territory as large as Lawrence, Lowell, and Lynn combined; the largest slipper city in the country, and with various other industries housed in modern and up-to-date factories.

As a water-works man, it is perhaps needless to add that we have the best and purest water of any city represented in this Association, supplied from five lakes and a storage basin; and that our rates are low and our service good.

Haverhill was the first city in the East to adopt the commission form of government, and we are one of the very few cities that has adopted modern charters where the water board was continued without change as a part of the municipal machine; a condition which I believe is correct and makes for greater efficiency. Every man who can get enough votes to be elected an alderman is not capable of running a modern water plant.

Under the act of 1891, creating the water department, it was provided that it be entirely separate from the other departments; hence we collect our water rates, handle the money and pay our own bills; the money being spent by the water board with certain limitations provided in the legislative Act.

I had worked with the former registrar for a good many years, and on succeeding him I kept on the bookkeeping in much the same way that he had handled it. We used to have a sheet of foolscap ruled off by hand, on which we entered our daily receipts as taken in. At the close of the day these were copied into an ordinary sized cash-book ruled with five columns. At times when business was good, we used to balance this cash-book daily; and at less frequent intervals during other seasons. We would perhaps strike balances eight or nine times a month. We also used what we called a classified cash-book, and in this the receipts were summarized covering the same number of days as the smaller cash-book. All payments were entered as in the smaller book. This classified cash-book had more columns than the small one, but many items had to be entered in a sundry column and had to be picked out for the monthly report and to charge in the ledger.

Our new charter provided that the accounts of the city should be audited by a competent accountant (this in addition to the audit by the city auditor), and four years ago this work was given to the Bureau of Statistics, who have done the work each year since. The statute under which this bureau makes audits of municipal accounts places the initiative entirely with the cities and towns, and at the present time 17 cities and 53 towns are taking advantage of the Act. As in all matters of this kind, the Bureau thinks that its system is the only one, and they propose a hundred and one things that make for more books and more expenditure of time and money. On the other hand, they have furnished me with some very practical ideas which I think have helped in a more intelligent classification of our accounts.

The auditor at once said to me, "You are spending all your time copying over lists of names that serve no good purpose and make for errors; get one cash-book ruled to carry most of your accounts, take a balance each day, but actually balance the cash-book only at the end of the month. You will thus save all this duplication, and your footings will show at once what each subdivision has taken in or expended for the month."

The suggestion looked good to me, and I planned out my present cash-book and have used it since, and find it highly satisfactory, and look back with sorrow on the time wasted through sixteen years.

The pages of the debit side of the cash-book are yellow and take about fifty entries to a page, both sides of the page being used. Those of the credit side are of white paper, printed on but one side, and at the close of the month these are bound in the cash-book following the debit sheets.

We have a stub covering every receipt, and these are entered in the cash-book at the close of each day; the cash is balanced daily and the result entered in a small book also suggested by the Bureau of Statistics.

The debit side (Fig. 1) keeps the receipts from water all at the left, with the amount of the bill in the first column; then abatements, discounts, and the amount of cash actually received entered in the column where it belongs. These five columns added together must agree with the total assessment column. The other receipts are entered in the columns set aside for them.

HAVERHILL WATER WORKS — RECEIPTS

Date	Name	Total Assessment	Abatements	Discount	Meters	Haverhill Fixtures	Bradford Fixtures	Other Years	Services	Bldg. Pur.	Rents	Interest	Real Est.	Iron Pipe and Specials	Old Material	Sundries		Cash on Hand

Fig. 1.

HAVERHILL WATER WORKS — PAYMENTS

Date of Bill	To Whom	Ledger Page	Voucher No.	Amt.	Construction.				General Maintenance.										Cash on Hand
					Mains	Services	Meter	Spec. Const.	Mtce.	Current Ex.	Stable	Kenoza Pump Sta.	Millvale Pump Sta.	Bradford Pump Sta.	Meter Mtce.	Crystal Lake Mtce.	Real Est. Mtce.	Sundries	

Fig. 2.

For the credit side (Fig. 2) I tried to arrange a cash-book that would clearly separate construction and maintenance accounts, giving so far as possible a column to each account; using similarly itemized vouchers for payments and a "distribution-book," such as is used by our city auditor, in which to enter the various items at the end of the month, the whole scheme having in view the annual report at the end of the year. This report has exactly the same subdivisions as cash-book, vouchers, and distribution-book, so that the making up of the financial part of the report takes only so long as it takes to add and verify the footings of the distribution-book.

Our cash-book is loose-leaf and, while I arranged it for my own needs, I utilized many valuable suggestions of the Bureau of Statistics. The binder is known as the Kalamazoo, which I would highly recommend as easy to handle, and especially as doing away with the post, which to my mind is a great drawback to most loose-leaf systems. This binder, made of pigskin, stands hard usage and we use it not only for the cash-book but for the register of water-takers. A desk-pad that just holds the loose cash sheets is used for the daily entries and is most convenient, the sheets being bound in the cash-book at the end of the month or oftener if necessary. The advantages as I have found them are:

1. Each receipt and expenditure entered in detail.
2. The items classified as entered.
3. A compact book with no wasted pages.

One of the first things I did after taking charge of the office was to introduce a voucher system. As I said before, we pay our own bills, and these are never sent out of the office with the check, but instead, the voucher (Fig. 3) containing the items of the bills paid, together with a receipt on the one side, and on the other, subdivisions of construction and maintenance, each subdivision itemized as it will later appear in the annual report. As the bills come in, they are checked and classified and the division of the plant to which they are to be charged is stamped on the upper right-hand corner of the bill. When paid, the voucher number is added and the number is also entered on the stub of the check-

book. We are never troubled with lost bills; the vouchers all come back, and the city auditor tells me that it has reduced the time used in checking up the payments in a manner that is satisfactory to him.

I regret to add that the Bureau of Statistics does not wholly approve. First, it thinks the city treasurer should pay the bills; second, it favors a voucher check. I hang to my voucher system, but keep my canceled checks well arranged for emergencies. At the end of the month, after our cash-book is balanced, the clerk goes through the vouchers for the month, bringing together in a book all similar items. These are then entered in our distribution-book. As I said before, our annual report follows the same plan and is simply a summary of the distribution-book.

In our ledger we carry the usual accounts of mains, services, etc., posting from the cash-book footings at the end of the month.

One other thing that the Bureau of Statistics called to my attention was what they call, I believe, a "master account." Previous to adopting this account I regret to say that we simply recorded our receipts, kept track of our unpaid water bills, and trusted we were getting all that belonged to us, but with no exact

HAVERHILL WATER WORKS.
HAVERHILL, MASS.

To *Fred F. Spinney,* Dr. Voucher No. *287*
Address, *Boston, Mass.*

1916 Date		ITEMS	Amount	
July	*17*	*Bill rendered*	*$31*	*50*

$ *31.50* Dated.................................

Received of the HAVERHILL WATER WORKS
the sum of *Thirty-one* and *50*/100 Dollars,
in full for the above account.

Signature.................................

Per.................................

☞ Please Date, Sign and Return this Voucher at once in Enclosed Envelope without Refolding.

FIG. 3. Reverse.

Voucher No. *287* Amt. $ *31.50*

HAVERHILL WATER WORKS

CONSTRUCTION		
(Mains)		
Iron Pipe and Specials		
Gates and Gate Boxes		
Lead, Packing, etc.		
Freight and Cartage		
Pay Rolls		
Sundries		
(Services)		
W. I. and Lead Pipe		
Valves and Boxes		
Oil, Gas, Wood, etc.		
Freight and Cartage		
Pay Rolls		
Sundries		
(Meters)		
New Meters and Fittings		
Pay Rolls		
Freight and Cartage		
(Special Construction)		
(Land Account)		
GENERAL MAINTENANCE		
(Repairs on Mains; Tools; Maintenance)		
Fuel, Oil, Salt, etc.		
Pay Roll, Maintenance		
Pay Roll, Maintenance M. P.		
Pay Roll	*7*	*10*
Tools and Repairs		
Repair Material, etc.		
Sundries		
(Current Expense Account)		
Salaries and Clerical hire		
Stationery, Printing, Postage, etc.		
Telephone		
Lighting		
Rent and care of Rooms		
Office Furnishings and Fixtures		
Sundries		
(Stable Account)		
Hay and Grain		
Horse Shoeing		
Horse Hire		
Rent		
Automobile		
Sundries		

(Kenoza Pumping Station)		
Salaries		
Extra Labor		
Fuel and Cartage		
Telephone		
Repairs and Tools	*3*	*50*
Freight and Express		
Oil and Supplies		
Sundries		
(Millvale Pumping Station)		
Salaries		
Extra Labor		
Fuel and Cartage		
Telephone		
Repairs and Tools		
Freight and Express		
Lighting		
Oil and Supplies		
Expense of House		
Sundries		
(Bradford Pumping Station)		
Salaries		
Extra Labor		
Fuel and Cartage		
Telephone	*8*	*40*
Repairs and Tools		
Freight and Express		
Oil and Supplies		
Expense of House		
Sundries		
(Real Estate Maintenance)		
Pay Roll		
Repairs		
(Meter Maintenance)		
Reading		
Repairs		
Express		
Crystal Lake Mtce		
Kenoza Lake Mtce		
Round Pond Mtce		
Lake Saltonstall Mtce		
Johnson Pond Mtce	*12*	*50*
Chadwick Pond Mtce		
Reservoir		

FIG. 3.

knowledge as to whether the yearly assessment was accounted for or not.

I now start the financial year charged with so much in unpaid bills of various kinds; I then charge myself with the assessment for meters, fixtures, labor bills, and all other bills sent out (Fig. 4). I am credited with abatements, discounts, and cash receipts; and these with the unpaid bills must total the same as the debit side.

ALBERT L. SAWYER * WATER REGISTRAR

In account with HAVERHILL WATER WORKS.

DR.		CR.	
Unpaid bills November 30, 1914	$2,905.30	By Cash receipts	$158,225.84
Water Assessment	178,127.19	„ Abatements (water)	3,582.35
Labor bills	19,502.71	„ Abatements (services)	110.03
Rents	1,209.08	„ Discounts	42,487.08
Interest	918.25	„ Unpaid bills (water)	75.69
Town of Groveland	1,126.00	„ „ „ (services)	1,942.71
Sale of wood	2,303.87	„ „ „ (rents)	13.00
Miscellaneous	344.30		
	$206,436.70		$206,436.70

Fig. 4.

We take a test balance each month except at water-bill time, when we have to take two months at once, and if we don't come out right, we have to dig till the mistake is found.

So many errors will creep in, one sometimes balancing another, that I believe this is a most accurate way of keeping things straight. We have had to go over thousands of stubs at times to find an error, but it is certainly a satisfaction to know that every cent is accounted for, while the fact that it must come right, and that errors must be found, is an incentive to the office clerks to be accurate.

As I had occasion to point out in a paper read at a previous convention of the Association, Haverhill has one of the oldest water-works plants in the country. I have brought with me the old cash-book of the Aqueduct Company, showing the first entry made in 1802, so that those who wish may compare the simple bookkeeping of the ancients with the somewhat more complex system demanded by present-day ideas as exemplified by bureaus of statistics, civil service commissions, and other supervisions foisted upon us by the paternal government of the old Bay State.

Note. — Discussion of this paper will be found on page 66, following the paper by Mr. Pride.

WATER-WORKS ACCOUNTING.

BY EDWIN L. PRIDE, CERTIFIED PUBLIC ACCOUNTANT.

[Read September 15, 1916.]

Mr. Fred G. Reusswig, in dealing with Uniform System of Accounting for Cities, says:

" Proper accounting does not of itself produce efficient administration, but it is generally conceded that proper accounts are essential to effective administration, to intelligent planning, and to sound appraisal of the results obtained. An adequate system of accounts in a city makes available, to the officers thereof, knowledge of the important facts relating to the cities' operations, and of the cost and efficiency of their administration, and, if the same system is used by a number of cities, makes possible the securing of trustworthy comparisons between cities, thereby increasing efficiency by placing a statement of the results obtained by one city before the officers of others so that all may profit by the experience of each."

I believe, therefore, that we are safe in starting off with the assumption that the advantages of uniform accounting are conceded. But, the minute we attempt to leave the starting point, we are confronted by obstacles in the form of differences of opinion as to how far we may go in the development of an accounting system without making it too complex for the fiscal officers of the smaller municipalities. In some places, the salary of the chief fiscal officer is so small that he cannot devote his entire time to his public work, and an involved system of recording transactions would take more time than he can afford to give. It also happens frequently that the chief fiscal officer, who is also the accounting officer, is selected because he is a man of known honesty, and the question of his ability to handle accounts never enters into his selection. These conditions alone give embarrassment to any one attempting to devise a practicable accounting plan, and the perplexities are multiplied when we come to consider the dissimilarity of financial provisions of various city charters. To over-

come these obstacles requires both skill and courage on the part of the accountant who undertakes the task.

The purposes of good accounting are to give information of the operations and reflect its financial condition. But, in order to do this, it is necessary that the accounts show the accurate and complete record, and this can only be done by adopting the accrued basis. Recording only sums received and sums paid out, without any reference to revenue which the city would receive, or the expenditures which it would have to meet, which would include not only amounts paid out but amounts of obligations incurred and not yet paid, is wrong.

In respect of revenues, the accruals are taken into account in the proposed system by setting up asset accounts for all accruing revenue items, and crediting them to revenue regardless of actual collections. As to appropriations, the proposed system requires that all orders, contracts, and claims, in other words, all encumbrances and commitments, shall be recorded on the books of the city and charged against the appropriation. This, together with the proposal of an inventory of material and supplies at the end of a year, makes it possible to ascertain the amount of expenses incurred during the year.

It will establish for each city standard accounts for revenues and expenses, so that the classification thereof will be uniform during all administrations, thereby enabling comparisons of expenses and revenues between years.

I do not know of any better "Uniform Classification of Accounts for Water Companies" than those prepared under the direction of the Public Utilities Commission in the state of Maine which were made effective July 1, 1915, and their instructions regarding each and every account are ideal to my mind; but I would like to call attention to one item — that is, what they say regarding

"W332. DEPRECIATION AND CONTINGENCIES.

"This account shall be charged periodically an amount, estimated or determined by some method prescribed by the officials of the corporation, which shall be sufficient to cover the cost of future replacements of tangible property, made necessary on account of gradual wear and tear and obsolescence and inadequacy

as have accrued during the period of such property, any portion of the intangible capital as may have expired during the period, and the amount estimated to be necessary to provide a reserve to cover the cost of property destroyed by extraordinary casualties. Amounts charged to this account shall be credited to the account known as 'Reserve for Depreciation.'"

I have testified as an expert in a great many water-works court cases, and I have maintained that a flat rate of two per cent. of the value of the water system (allowing fifty years for the life of it as a whole) annually is a fair charge against the income.

My friend Harvey S. Chase, certified public accountant of Massachusetts, said, — and others have said the same thing, — and I believe you all agree (though you may differ with me on the rate or the method of depreciating),— rates cannot be just unless full allowances shall have been made for deterioration of the plant, or, in other words, for the capital losses which arise from depreciation, such losses must be provided from income, or otherwise they will require new capital. Therefore they should be handled in the accounts as regular charges against income.

Whenever depreciation is made good by actual expenditure for renewals or reconstruction, such amounts should be charged against the reserve for depreciation, and the balance remaining in this account will show whether or not the sufficient allowances are being made year by year to provide for depreciation losses.

Auditors, comptrollers, and managers are seeking for light upon this subject, and all men who make studies of municipal affairs become convinced of the necessity for uniform and standard methods for handling depreciation which should be identical in, and mandatory upon, both public service companies and municipal enterprises.

If we leave the allowances to be made for depreciation to be estimated or determined by officers of the corporation, I am afraid, in comparing the different returns, we would find them to be anything but uniform.

I am not "fussy" as to the bookkeeping, whether accounts should be kept in bound ledgers, loose-leaf ledgers, or on cards. There are good arguments in favor of each; but I am particular as to the accounts.

One general "plant account," representing all the land, buildings, reservoirs, dams, distribution mains, meters, services, equipment, etc., and one general "expense account," are not what I would recommend. An up-to-date system of accounts to-day must be one that can clearly and quickly answer any and all questions.

The plant account must be divided so that we will know what makes up this account to a unit. The revenue and income must be segregated so we can know from what sources they are derived. The expenses must be kept almost minutely. These are essentials in the management of any business or operation of any water works.

When these results are obtained, then we have something that is helpful, and comparisons are valuable.

Discussion.

Mr. Walter P. Schwabe.* I feel that the introduction of Mr. Sawyer's paper is very important to this Association. I believe the accounting part of the water department companies has been sadly neglected as to its standing and the place it occupies. A proper system of accounting is of vital interest in the management of our business. It gives us figures for comparison, so that the engineers or executive can find out what they are doing in relation to similar work in other parts of the country, or other companies in the same state.

The present requirements of utilities commissions and bureaus of statistics mean a considerable amount of work, as far as accounting is concerned; and it will be well for water companies to unite on certain classes of uniform accounting, so that these bureaus and utility commissions, when they are looking for certain information, can get it, without each utility commission forming its own classification, or each bureau of statistics, and every one reporting in a different way, so that there is absolutely no chance for any comparison whatever.

I trust that these papers, this presentation here, will lead to the appointing of a committee by this Association. I think that

* President and General Manager, The Thompsonville Water Co., Conn.

is absolutely necessary. Much can be accomplished by an accounting committee, and you will find utilities commissions will confer with them in formulating their accounts. It has proven so, in the case of electric and gas utilities. The accounting committees of these national organizations are very important, and in their meetings in recent years one day has been set aside for accounting systems. From that point of view, I believe these papers are perhaps the most important we have had during this session, and I trust they will lead to the appointing of an accounting committee that will be permanent.

Mr. S. H. McKenzie.* I wish to second what the gentleman has said in regard to accounting, from some little experience I have had, especially in one of the small companies in Connecticut, where I have come to realize the great importance of it. Our public utility commission recently got out an order requiring quite extensive reports, and a great many of our smaller companies were not in a position to answer or fill out those reports. So I got up a set of books for the one small company with which I am connected; and, in order to save expense for ourselves, I got them up in such a way that they could be used by other companies, and have introduced them in several different places. In one place, for instance, when I came to take the books of the company and try to make up the report, I found they had simply a cash book, and they couldn't tell whether they were making or losing money, and were surprised, when the report was made out for them, to find that they were going in the hole each year. That one incident alone, though there are others, makes this matter to my mind very important, and I hope that the Association will appoint a committee to study further into the matter and see if a uniform system cannot be gotten up; and, if such a committee is appointed, I think they should consider also the smaller companies. They are not in a position financially to adopt the expensive systems which the larger companies are using, but must have something which will answer their needs.

We are using a simple form of cash book in which the items are all entered, and then, at the end of the year, — and sometimes at the end of six months, depending on the size of the company, —

*Engineer and Superintendent, Water Dept., Southington, Conn.

SHEET NO.______

WATER WORKS DEPARTMENT

RECORD OF RECEIPTS IN MONTH OF *19*

			Credit					Deductions				Net	Amount	
Day	From	Pays	Acct. No.	Misc.	Forfeits	Accts. Rec.	Water Rent	Acct. No.	Water Rent Vac.	Acct. No.	Misc.	Amt Rec'd	Date	Deposited
	Brought Forward													

DISBURSEMENTS

SHEET NO.............

Record of Checks Drawn on..................*in Month of*..................*191*....

Date	To Whom Issued	Pays	Charge Acct. No.	√	Detail	Amount	√	Check No.	Deposits		Balance
									Date	Amount	
	Amounts brought forward,										

FIG. 5.

RECEIPT AND DISBURSEMENT SHEETS USED BY SEVERAL SMALL WATER DEPARTMENTS IN CONNECTICUT.

.......................WATER CO.......................CONN.

FINANCIAL STATEMENT FOR *ENDING*

ASSETS				LIABILITIES			
No.	Account	Detail	Total	No.	Account	Detail	Total
C-1	CASH: Nat'l Bank			20	Capital Stock		
C-2							
C-3				22	Bonds Issued		
C-4	Funds Advanced						
B-1	BOOK: Water Rents Due			24	Notes Payable		
B-2	Accounts Receivable						
B-3	Notes Receivable			26	Accounts Payable (Current)		
M-1	MATERIAL: Construction Supplies						
M-2	Tools			28	Interest Accrued (but not due)		
1	PLANT & EQUIPMENT: Organization						
4	Water Collecting System						
6	Pumping System						
7	Distributing System			30	Reserve for Depreciation		
8	General Structures						
9	General Equipment			32	Reserve Account		
12	Engineering & Superintendence			35	Surplus (Profit and Loss)		
13	Law Expenditures (Const.)						
14	Injuries (,,)				Total Liabilities		
15	Taxes (,,)				Current Net Gain		
16	Misc. Construction				Total		
17	Interest during Construction						
					MEMO.		
					Surplus on..................		
4-A	NEW CONST.: Water Diversion Rights				Current Income & Expense		
4-B	Reservations				Interest Received		
4-C	Impounding Dams and Res.						
4-E	Springs & Wells				Interest Paid		
4-G	Collecting Cond. & Res.				Dividends Paid		
4-H	Gravity Intakes & Suction Mains						
4-I	Supply Mains				Present Surplus		
6-A	Pumping Station						
6	Pumping Equipment						
6-F	Misc. ,, ,,				TRIAL BALANCE	DEBIT	CREDIT
7-A	Transmission Mains				Assets		
7-B	Distributing Reservoir, Tanks				Liabilities		
7-C	Distributing Mains				Sales		
7-D	Service Pipes, &c				Miscellaneous Gains		
7-E	Meters				Operation		
7-F	Fire Hydrants				Maintenance		
					Salaries		
					Office Expense		
					Miscellaneous Expense		
					Interest & Dividends Paid		
	TOTAL ASSETS						

FIG. 6. FINANCIAL STATEMENT SHEET USED BY SEVERAL SMALL WATER DEPARTMENTS IN CONNECTICUT.

STATEMENT OF SALES AND EXPENSE FOR   AND PERIOD ENDING   19

		Current			Fiscal Year to Date			Last Year
No.	Account	Detail		Total	Detail		Total	Total
40	Sales: Fix. Rates, Dom., Stores, &c.							
41	,, ,, Factories							
42	,, ,, Public Uses							
44	Meter Rates, Dom., Stores, &c.							
45	,, ,, Factories							
46	,, ,, Public Uses							
48	Hydrants, Public							
49	,, Private							
50	Other Fire Protection							
52	Street Sprinkling							
54	Miscellaneous							
	Total Sales							
60	Misc. Gains: Interest Rec'd							
61	Forfeited Discounts							
62	Miscellaneous							
	Total Gross Income							
71	Operation: Collecting System							
72	Pumping ,,							
73	Distributing ,,							
74	Miscellaneous							
76	Maintenance: Collecting System							
77	Pumping ,,							
78	Distributing ,,							
79	General Repairs							
81	Water Purchased							
82	Salaries: Gen. Officers and Clerks							
83	Office: Rent							
84	Office Expense							
85	Misc. Expense: Taxes							
86	Insurance							
87	Legal Expense							
88	Accident							
89	Uncollectible Accts.							
90	Depreciation							
94	Income and Expense Summary							
95	Surplus: (P. & L.) Int. Paid on Bonds							
96	Interest Paid on Notes							
97	Dividends Paid							
100	All Labor (Memo.)							
	Gain or Net Income after Payment of Interest and Dividends							

Fig. 7. Reverse of Fig. 6.

they are brought together and made out on a separate sheet. It is a little different from what we use in private companies, but to my mind it is a very simple statement, and places before our board on one sheet of paper the entire profit of the company for one, two, or three years. (See Figs. 5, 6, and 7.)

MR. W. C. HAWLEY.* Mr. Pride has brought up the matter of depreciation. I wish he had carried the matter a little further, but as he did not, I want to ask him a question or two. In the first place, as to the rate of depreciation, I cannot understand how a uniform rate of, say, two per cent. can be applied to all plants. In the first place, there is a question how you are to carry your rate. On a gravity plant, the rate of depreciation will be materially less than on a pumping plant. In a town that is growing rapidly, your depreciation will be much less than in a town whose rate of growth is comparatively small. All these things must be taken into consideration.

In some studies which I have made, I have found a rate on the sinking fund basis to vary from about one half of one per cent. to as high as one per cent., — perhaps one and a quarter would be a fairer rate in that particular case. So, it seems to me, in each case the rate must be determined by an actual study of the units of the plant, applying the proper life and figuring out what the depreciation would be on that basis.

I should like to ask Mr. Pride what his idea is as to how a depreciation reserve fund should be carried. Those of you who are familiar with what has been done by the Association in the Central West, probably know that in many cases where there has been simply a bookkeeping entry made of depreciation, the commissioners assumed the depreciation, instead of having been actually put aside, has been paid to the stockholders. I am speaking of private companies, of course. Therefore depreciation has been subtracted from the value of the plant for rate-making purposes. That is a rather dangerous proposition. If we are to be penalized in that way, it seems to me we have got to be pretty careful, and that probably a better plan would be to actually create a sinking fund, or depreciation fund, putting the money into it, having a really tangible thing, perhaps with a commissioner or trustee,

* Chief Engineer, Pennsylvania Water Co., Wilkinsburg, Pa.

and then that money being invested either in securities, or, in the case of a private company, perhaps, by the company, but invested in construction, the company giving its note to the trustee or commissioner for the amount so borrowed, and paying interest thereon. Then the money, in the case of depreciation calculated on the sinking fund basis, is in the plant. It is simply making up the difference between the percentage of valuation of your plant and one hundred per cent.; and that is, the actual value of your plant and the one hundred per cent. valuation that you started with.

I would like to know what Mr. Pride thinks about the actual creation of such a fund. The Wisconsin Commission has already put forth some very excellent forms of water-works accounting, and doubtless, if a committee of this Association is appointed, their forms can be studied with profit. It will be a very helpful committee, I think.

Just one other matter in the case of a community which has grown very materially. I believe that in many cities a material saving can be made in the matter of meter reading by distributing your readings along monthly, or semi-monthly, as the case may be, instead of trying to read your meters all semi-annually or quarterly, or perhaps reading them all every month. In our plant, where we have some 14 000 or 15 000 accounts to keep, we have divided our territory into districts, and we are reading every two weeks. We read the meters at the beginning of the month. So in two weeks the bills go out, and then the next district. In that way we are able to cover our ground with about one third as many meter readers as we had, and they still have time to do a considerable amount of meter repairing. We do not have a great crowd of people coming to our office to pay their bills. They come along gradually. We are able to handle them with less office help, and we have found it to work out very nicely, and to give us quite a material saving.

Mr. Sawyer. Now that we have got the accounting end of the Association started, I wonder if it would not be a good idea to get something in concrete form, perhaps. I think I would make a motion that a committee be appointed on accounting. Possibly, in going over the ground, they could suggest something

that would be of help to all of us in standardizing our accounts. I understand perfectly well the conditions are so different in different places. For instance, Mr. Pride spoke of appropriations in the case of cities. We do not have any appropriations; we simply have all we take in, and spend that; that is, we do not have any appropriations at all from the city.

Mr. King. Some six years ago there was a meeting in Washington, under the direction of the census bureau, at which this matter of accounting in water works was discussed for several days. Prominent accountants from Baltimore, from Boston, and New York, were present, and the matter was thoroughly discussed, and the Government has published a report of the recommendations to that committee, and it will be found in their publication; I think we have one of the reports in the Library.

Mr. Sherman. The matter which Mr. King has called attention to is one which has not been as widely known among our members, and among water-works men generally, as it should be. The committee, if it can be called a committee, which got together at that time, did a very valuable work, and the publication issued by the Bureau of the Census, formulating the results of that conference, is very suggestive, and contains very much information of value. It, however, has occasionally been put to unfortunate uses, and that is a fact which I wish to call attention to at this moment. That schedule is sometimes quoted as having been adopted by the New England Water Works Association and other associations, apparently from the fact it was formulated by a body of men containing representatives from those several associations. It, however, cannot be too strongly borne in mind by any one having occasion to use it, that, as good as it is, it contains some points which are perhaps still open to discussion, and which never have been formally adopted, — certainly by this Association, nor, I think, by the American Association,— nor has it ever been submitted to them for adoption. It was draughted by the Bureau of the Census, following this conference.

Mr. Fuller. If my recollection is right, there was a committee appointed, and they got out a schedule. Whether it was actually adopted by the American Water Works Association, I am

not sure. Certainly a committee was appointed and got out some schedule on uniform accounting.

Mr. Sherman. Mr. Fuller is quite right on that. The American Association had a committee which took part in the discussion, of which a gentleman who took part in the Washington discussion was chairman. They got out a pamphlet of, I should think, one hundred and fifty pages, giving very detailed statements of the accounts recommended, but I have been unable to find out that the American Association ever did anything with the report. It does not appear in the American Association's publication. They got out this advance copy, which I have had, and which has been very useful, but although I have hunted carefully through the proceedings to find what they did with it, I cannot find that they took any action on the report of the committee, or ever published the report in their transactions.

Mr. Fuller. Some of the public service commissions have adopted standard methods of accounting, which are along the general lines outlined in the American Water Works, but very much simpler. My impression is those are compulsory in the state of New Jersey. They certainly have a uniform system of reporting, and I think of accounting, at least for private companies.

President Sullivan. I find that public utilities commissions and service commissions take a broad grasp of these things, and include in classifications and uniform accounting, problems that are kindred to some extent, such as gas, water, and electricity. They have large problems. Some of us who get reports to be filled out find that they are very nearly analogous to the gas company or electric light company, or something else. So I think the Association itself would do well by having a committee appointed to study it. We would be the gainers. We would obtain the information they would gather, and use it or not use it, as we saw fit.

Mr. Bacon. I would like to make a supplementary motion to the effect that the committee take into account the previous investigations of uniform accounting made by other water-works associations, by the Bureau of the Census, and by the various public utility commissions. I would like to make a motion to amend the motion before the house.*

* For the appointment of the committee see Journal N. E. W. W. A., XXX, 513.

Mr. Sawyer. I wish to make a suggestion. I think that at some time, at some future convention, it will be very interesting to the water registrar end of it, in particular, if we could have some kind of an exhibit by the water registrars. In other words, suppose each office could come to the convention with a card, or a small sample of their forms. I have found by visiting other offices you get a great many ideas. Some things you can't adopt altogether, but you can get something that is applicable to your office. I think it would be interesting if we could not only have water valves but have a little booth devoted to the registrar, so we could bring down something that we could all come and look over and see if there was anything that we could put into our own offices, which we were not already using.

President Sullivan. I think that educational feature is a very good suggestion; and I trust, when the committee is appointed, they can evolve some scheme whereby they can show what they use in accounting.

Mr. Pride. I wish to reply to the gentleman in regard to his depreciation suggestion, in support of my suggestion of a two per cent. allowance for depreciation, yearly. I use the factor of two per cent. on account of allowing that the life, as a whole, of a water-works structure is fifty years, and I do that so as to get at some basis for uniform accounting.

It is true that no water-works plant, or the soil, or the water in all places is alike, and we cannot have the same depreciation in one place as we get in another place, but if we set up a two per cent. depreciation on the whole plant, and deduct that depreciation from our earnings before any dividend is declared, set it one side, take it out of our earnings and have that to take care of a depleted plant, and then have all our material, — that is, in the way of construction — and replacement charged against that depreciation, we will then see whether or not we are setting aside enough to take care of our depreciation. It is the physical loss that I wish to take care of. The sinking-fund method, almost always, takes care of a lot of bonds that are out. You set aside the cash to take care of those bonds, but there is no provision made to take care of the deterioration of the structure.

I feel that if we adopt a uniform system, we know on a com-

parable basis what all the other water plants are doing, and we can see whether or not they are running on a percentage basis the same as the other plant, or more, and it will be helpful to us, and guide us in our water-works accounting.

Poor old Boston & Maine would never be in the condition it is to-day if depreciation had been taken care of before dividends were declared.

Mr. Sherman. While the matter of depreciation is under discussion, another word may not be out of place. It is, of course, extremely necessary, in handling water works and other public utilities, to distinguish carefully between annual charges for depreciation and what has been called accrued depreciation, or the loss in value of the plant as compared with its original cost. The latter item is perhaps of not great, certainly not of controlling importance in the operation of the plant, but, in the accounting connected with it, it is of considerable importance at intervals in making any comparison of the actual value of a plant with the indebtedness standing against it, particularly in the case of a private company, but perhaps most so in the case of a municipally owned plant. It is, of course, of immense importance at the time of the appraisal of a plant for purposes of taking by municipal authority from a private company. In that case, it is of great importance to know what the real value of the plant is at the time of taking, and one method of estimating that, commonly employed, is to estimate the reproduction cost, or obtain the original cost as the case may be, and deduct the estimated accrued depreciation.

In operation, it is essential to set aside, as Mr. Pride has so forcibly pointed out, a sufficient sum to cover on the average the loss of value accruing during the year; whether that is done by setting aside year by year a fixed percentage of the cost of the plant new, or whether it is done by some other method, is of comparatively slight moment; as long as a sufficient sum and not an unreasonable sum is set aside. For many reasons, in many cases, it seems to me that the most satisfactory method in accounting for annual charges is to take a fixed percentage of the gross revenue; the revenue, particularly in water plants, is usually reasonably closely fixed, in any particular plant at least, in its relation to

the value of the works. If a definite percentage of that revenue is applied to depreciation reserve, just as a definite amount must be used in the case of a privately owned plant for paying taxes, those charges are taken care of automatically. Of course, you can only tell whether a reasonable sum is being set aside by making an appraisal at intervals of five or ten years and comparing the real value of a plant as it then exists with the cost, and the sums which have been set aside or charged off as depreciation.

ON THE NATURE OF COLOR IN WATER.*

BY THORNDIKE SAVILLE, ASSISTANT IN MUNICIPAL ADMINISTRATION, HARVARD UNIVERSITY.

[*Read December 13, 1916.*]

The writer has been engaged in a study of the problem of color removal from water, and in connection with the experiments which he has carried on, application has been made of some of the newer ideas of physical chemistry. The investigations described herein were undertaken with a view to proving or disproving the colloidal theory of color in water, and the discussion of results and conclusions are largely confined to that problem.

The question of color removal from public water supplies is being studied by many engineers. It is not so much a question of hygiene as of esthetics; not so much a provision to safeguard the health of a community as to cater to that psychological attribute which makes a clear and colorless water *seem* more salubrious than a turbid or colored water.

Present knowledge concerning the nature of color in water is far from satisfactory. From this lack of information there results the use of inadequate and often troublesome methods of removing color from public water supplies. The studies reported in this paper are, therefore, only a contribution to the larger study of color removal, and they are presented as offering possible new departures in the technique of color removal practice.

The investigations made by the writer have been only upon waters from localities along the Atlantic Coast.

The Present Conception of Color.

The origin of the brown color of water is generally considered to be due to chlorophyll or its allied products derived from dead and decaying vegetation. Carbon, hydrogen, oxygen, and iron have been shown to be important elements of the coloring material.

* No. 1 in "Studies on Decolorization of Water," Contributions from the Laboratory of Hygiene and Sanitation at Harvard University.

In general, the greater the amount of iron in a water, the greater will be its color. The color is usually some shade of brown, either yellowish or greenish brown; the change from one to the other often being seasonal.

Until comparatively recently, the physical nature of the color in water has received little attention. It used to be stated that (1)* "color is due to substances in solution, while turbidity is due to substances in suspension." Moreover, (2) "tannins, glucosides, and their derivatives are doubtless present. . . . Carbon is the important element in its composition, and the color varies in amount very closely with the 'oxygen consumed.'" That "coloring matter (in water) is similar to, and possibly identical with, the coloring matter in tea" (1, 2) has been generally accepted as a satisfactory explanation of the character of the coloring matter. These statements represented the current views on the question of the nature of color in water which have been held until lately. Recently studies have been made which will doubtless cause these earlier theories to be somewhat modified.

The belief has been slowly gaining credence that coloring matter in water is essentially colloidal in nature, and does not primarily exist in true solution. It is the aim of this article to show that color in water is certainly in the colloidal state, and that it exhibits definite and characteristic electrical properties which substantiate this contention.

The Nature of Colloids.

To make more intelligible the discussion of the material presented in this paper, a brief résumé of the underlying theory is attempted in the following paragraphs. This is the more desirable since, to the writer's knowledge, no such statement of the colloidal theory as applied to color in water is available, except in two somewhat contradictory articles by Catlett (3, 4).

At the outset it is important to define a colloid. The whole study of colloids is of such recent development that the nomenclature is as yet unsettled and often contradictory. The terms given below have been taken from the latest writers on the subject, and indicate the most recent views.

* Figures in parenthesis refer to titles in the bibliography appended at the end of the paper.

"A colloidal solution may be defined as a suspension, in a liquid medium, of fine particles which may be graded down from those of microscopic to those of molecular dimensions. The one property common to all such solutions is that the suspended matter will remain almost indefinitely in suspension in the liquid, the natural tendency to settle due to the attraction of gravitation being overbalanced by some other force tending to keep the small masses in suspension (5)." It has been shown that nearly all substances exist in the colloid condition if finely enough divided or properly prepared, and hence we now speak of substances as being in the colloidal state rather than of certain substances as colloids. The size of particles to be in the colloidal state is generally taken to be from 0.001 mm. to 0.0000001 mm.

There are two major classes of colloids: (*a*) viscous, gelatinizing mixtures, not readily coagulated by salts, such as gum arabic, gelatine, glue, etc.; and (*b*) non-viscous, non-gelatinizing, readily coagulable mixtures. The first types are known as *emulsoids*, and may be considered as suspensions of one liquid in another liquid, as globules of fat in water. Those of the second type are called *suspensoids*. The latter consist of very finely divided particles in suspension in a liquid, and as color in water is supposed to exist chiefly in such a state, this is the only class of colloids which we shall consider. It is probable that the color in some waters, and possibly some of the color in all waters, is in the emulsoid state. The conclusions arrived at in this paper, however, are thought to be valid whether color in water is conceived of as a suspensoid or an emulsoid colloid.

Color in water is postulated as ordinarily a suspensoid colloid. The colloid particles, though invisible to the eye or under the microscope (colored water is often quite clear), are visible in the Tyndall ray (6). This is a device which makes use of a beam of reflected light passed through the colloid solution. The colloid particles are thereby rendered visible. The phenomenon is similar to that by which dust particles in the air, ordinarily invisible, are made visible in a beam of sunlight. If the illuminated particles be now viewed through a microscope, their character can be ascertained. This combination is known as the ultra-microscope.

It was early found that ordinary suspensoids moved to one or

the other electrode when an electrical current was passed through the liquid. This phenomenon has been called *cataphoresis*. The electrode toward which the suspensoids move is dependent upon the character of the charge which they carry, those negatively charged moving to the anode (and being called anionic suspensoids), while those positively charged move to the cathode (and are called cationic suspensoids). Certain substances when suspended in a colloidal state in water exhibit these characteristics, and in the following discussion it will be well to have in mind certain typical suspensoid members of each class * (5).

"The fundamental assumption is that when a particle suspended in a liquid becomes charged, there exists about it a double electric layer; when the particle is negatively charged, there is a layer of negative electricity on the surface of the solid particle, while in the liquid immediately surrounding it there is a corresponding layer of positive electricity"; and vice versa for positively charged particles (5).

"In regard to the cause and character of the electrification, the phenomenon has been expressed by the term 'contact electrification'; the particles becoming charged by the rubbing of the moving particles of the liquid itself against the suspended particles" (5).

It has long been known that when certain salts such as $Al_2(SO_4)_3$ (the "alum" of water supply terminology) are added to water, a flocculation and precipitation takes place.

Hardy (7) has shown that this is a colloidal phenomenon, the

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* Anionic Suspensoids.

1. Sulphides of arsenic, antimony, and cadmium.
2. Suspensions of platinum, gold, silver, and mercury.
3. Vanadium pentoxide.
4. Stannic acid and silicic acid.
5. Aniline blue, indigo, molybdena blue, eosin, fuchsin, Prussian blue.
6. Iodine, sulphur, selenium, shellac, resin, kaolin, quartz.
7. Starch, mastic, caramel, chloroform.
8. Silver halides.
9. Various oil emulsions.

Cationic Suspensoids.

1. Hydrates of iron, chromium, aluminum, copper, zirconium, cerium.
2. Bredig solutions of bismuth, lead, iron, copper.
3. Hofmann's violet, Magdala red, methyl violet, Bismarck brown, methylene blue.
4. Albumen, hemoglobin, agar.
5. Titanic acid.

$Al_2(SO_4)_3$ forming aluminum hydroxide* which is in colloidal state. He formulates two rules for flocculation by electrolytes, as follows:

1. The coagulative power of a salt is determined by the valency of one of its ions. This preponent ion is either the negative or positive ion, according to whether the colloidal particles move up or down the potential gradient.

2. The coagulating ion is always of the opposite electrical sign to the particle.†

APPLICATION OF THE COLLOIDAL THEORY TO COLOR IN WATER.

If the foregoing hypotheses are correct, and if we can apply them to interpret the nature of color in water, the following facts should be borne out in practice:

(1) If color is due to particles in the colloidal state, and such particles are merely minute masses of matter in suspension, then, given time, we ought to get decolorization by gravity alone. Under ideal conditions of quiescence and constant temperature, such might be the case. Practically the particles are so small, and are influenced to such an extent by convectional currents and wind, that it is quite feasible to keep them in suspension indefinitely by mechanical means alone. Add to this, that if, as we postulate, each particle carries a similar charge of electricity, there is a mutual tendency to repulsion, and in this way also the suspensoid phase is continued despite gravitative influence.

Moreover, as the velocity of a particle falling in a liquid is, according to Stokes (8), given by the formula $V = \frac{r^2(s-s')g}{gn}$ where r equals radius of particle, s equals specific gravity of particle, s' equals specific gravity of liquid, n equals viscosity coefficient, and g equals gravity constant, it will be seen that the velocity of settling is proportional to the square of the radius. Thus in a particle having a size of 10 microns,‡ the size of a gold sol,§ the

* It is now generally considered among chemists that the compound heretofore called aluminum hydroxide is really hydrous aluminum oxide having the formula $Fe_2O_3 + ?\ H_2O$, instead of $Fe_2(OH)_3$.

† See footnote, page 91.

‡ 1 micron = 0.001 millimeter.

§ See footnote, page 88.

velocity of settling under the influence of gravity alone and under ideal conditions is at the rate of 10 mm. per month. If, now, "the flocculation of particles increases the effective radius, flocculation must have the effect of greatly increasing the rate of sedimentation and, therefore, of clearing of suspensions (9). This is in fact the chief way in which flocculation is made manifest, and from this fact comes the common use of the word flocculation as signifying the rate of clearing of a suspension."

(2) If the color be due to colloidal particles in suspension, then they should be coagulated by electrolytes and in accordance with the laws of Hardy (page 82). If all the color colloids carry the same charge, they mutually repel each other, and so tend to remain in suspension. If an electrolyte be now added carrying an opposite electrical charge, flocculation should occur. This is precisely what happens in greater or less degree, but in less simple relations.

As the writer hopes to show hereafter, color in water may carry either a positive or a negative charge. When the color is positively charged, it is removed by alum chiefly by mechanical action, and an overdose of alum will be needed to form a heavy enough precipitate to carry down the suspended color particles. In the case of negative color, both the positive aluminum ion from $Al_2(SO_4)_3$ and the positive aluminum hydroxide formed produce neutralization of the negative charge on the color colloid. Hence there is in the case of negative color a flocculation from these causes as well as the mechanical action of the hydroxide. The underlying theory of these reactions is explained in detail in the footnote on page 91. It is a theoretical consideration and has not as yet been entirely substantiated by experiment.

If color is colloidal in nature, it should be concentrated upon boiling and evaporation of some of the water. This the writer has found to be true, an increase in color proportional to the concentration by evaporation being obtained, and also an increase in opaqueness of the liquid when viewed in the Tyndall ray.

(3) If the color be colloidal, then it should be electrically charged and move in an electric field. If a current be passed through the liquid, there should be a concentration of color at the electrode of opposite sign to the charge borne by the color suspensoid. With

continued application of current, the color in the vicinity of the electrode of the same sign as the charge on the color particles should be reduced to zero. Finally, the discharge of color particles should occur at the electrode of opposite sign, with consequent flocculation and reduction of color there also. The experiments of the writer have been conducted to investigate this phenomenon, and the results seem to entirely justify the conclusion that color in water must be chiefly colloidal in nature, and that it does obey the laws of cataphoresis as outlined immediately above.

Apparatus.

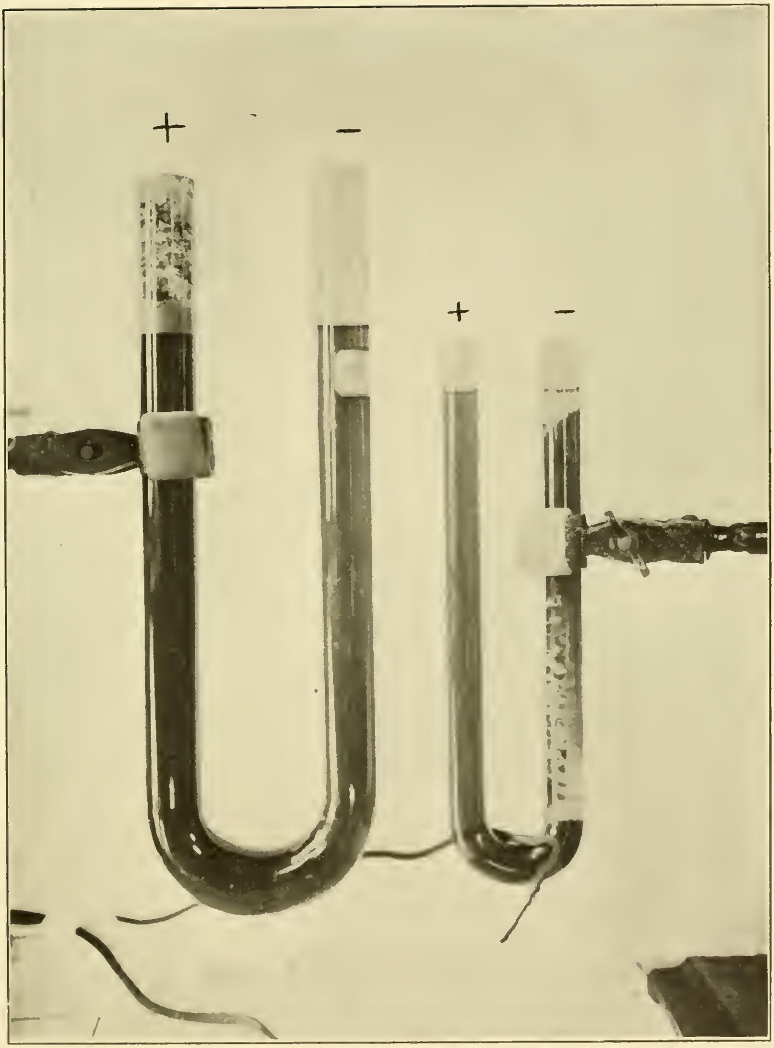
The apparatus used was simple, consisting at first of glass U-tubes varying in size from $\frac{1}{2}$ in. in diameter with 6-in. arms, to 1 in. diameter with 8-in. arms. These were filled with the liquid to be investigated. Electrodes of platinum wire were used, immersed directly in the liquid and connected to a 110-volt d. c. current. The amperage obtained was usually in the vicinity of one milliampere.

Later a somewhat more elaborate tube has been used, fitted with a stopcock at the bottom, so that, when samples were being extracted, each side of the tube could be cut off and prevent any mixing of the liquid. It was found that in the simpler tubes there was a likelihood, especially when there was a precipitate, of causing a disturbance and mixing in the two arms when withdrawing a sample. The arrangement of wiring and general appearance of the apparatus is indicated by Plate II.

Description of Experiments.

1. on tea.

The investigation was begun during the winter, when highly colored waters were difficult to obtain in the vicinity. Earlier experimenters, Hollis, Brown, and Whipple, had all utilized leaf extracts in studies of color. In view of the fact that Hazen and others (2) so persistently advocated the similarity between the nature of color in tea and in water, the writer began his experiments with tea extracts.



Tube at left shows tea extract after being subjected to cataphoresis for 300 hours. Tube at right shows tea extract after cataphoresis with copper electrodes.

At once the phenomenon of cataphoresis was evidenced. There was almost constantly throughout the experiment a decided difference in color between the two limbs of the U-tube, showing the particles to be moving toward one electrode and away from the other. To obey the laws of cataphoresis in their entirety, there should have been a continual decrease in color on one side, and a continual increase in the other side. That this is far from being the case is shown by Table 1. Here it is seen that for the first forty-two hours there was a sudden rise in color in both arms of the tube, the positive arm continuing to rise for sixty-eight hours and then dropping somewhat more slowly than the negative arm. Both arms, however, continue to lose color with time, the positive arm remaining slightly more highly colored than the negative.

In Plate II, to the left, is shown a tube with tea extract after three hundred hours' run. The difference in color is noticeable, that in the positive arm being greater. There is also a heavy froth on top of the liquid in the positive arm, and in consequence there has been a holding back of the oxygen gas which is liberated at this electrode and a pressure developed which is manifest by the slightly greater height of the liquid in the negative arm.

The explanation of the sequence of events in this experiment is not entirely clear, but the writer interprets them as follows: The increase in color at first is due to oxidation of iron or some other element in the liquid, brought about by the oxygen at the positive pole. Some other electrochemical effects are doubtless active. The increase in color ceases when the chemical action producing it has been completed, and the cataphoresis, which has been masked, is now evident. The passage of particles toward the positive electrode is seen, and hence the colloid particles carry a negative charge. Discharge, flocculation, and precipitation at the positive pole occur, with reduction in color. Color reduction is greatest in the negative arm, from which the particles move, and least in the positive arm, toward which they migrate.

The increase in the suspensoid phase in the positive arm increases the viscosity of the liquid, and consequently the oxygen gas escapes less readily and a froth forms. The formation of froth is characteristic of many cataphoresis experiments in water and indicates ordinarily the side to which the color moves. Large

TABLE 1.

EXPERIMENTS ON TEA EXTRACTS.

Experiment No. 1.					Experiment No. 2.			Blank	
	Large Tube. Platinum Strip.		Small Tube. Platinum Wire.		Large Tube. Platinum Wire.				
Hours.	Color, p.p.m.		Color, p.p.m.		Hours.	Color, p.p.m.		Hours.	Color, p.p.m.
	+Arm.	−Arm.	+Arm.	−Arm.		+Arm.	−Arm.		
0	2 750	2 750	2 750	2 750	0	4 300	4 300	0	2 750
3	2 900	3 400	....	....	6	5 200	5 100	42	3 200
22	4 200	5 000	....	....	11	5 500	5 000	261	6 000
42	5 700	3 300	5 200	5 200	20	6 700	6 000	384	7 100
68	5 800	2 300	5 500	1 000	28	7 000	5 500	504	7 100
76	6 000	2 300	5 500	1 000	34	8 600	3 800	648	9 600
93	6 200	2 400	5 100	800	48	8 000	3 500	...	....
125	5 500	2 800	3 300	3 300	56	11 000	3 500	...	....
149	5 500	3 700	2 700	300	63	9 600	3 200	...	....
214	3 700	3 300	1 200	200	72	10 000	2 700	...	....
261	3 600	3 100	300	50	80	10 000	2 400	...	....
288	3 400	3 400?	....	....	88	11 000	2 800	...	....
384	3 300	3 100	180	....	96	7 300	2 500	...	....
504	....	....	....	....	107	10 000	2 300	...	....
648	....	....	....	....	118	9 000	1 800	....	....
...	....	....	....	....	170	6 900	1 600	...	....

masses of flocculated material accumulated at the bottom of the positive arm, showing the color to be charged negatively.

In Plate II, on the right, is shown a tube with tea extract, which was subjected to cataphoresis with copper electrodes instead of platinum. Here there was a very rapid coagulation, the color decreasing from 4 600 to 250 in twenty-four hours. The copper goes into solution, forming an electrolyte, and the color is drawn to and deposited upon the anode.

A number of samples of tea extract were kept under differing conditions for observation as to changes of color. Very evidently there is a slow oxidation going on, as the color in the blank sample rises continuously. The results are tabulated below.

Time.	Unstoppered.	Stoppered.	Stoppered and Sterile.	Unstoppered and Sterile.	Sterile and in Dark.
1 day	3 000	3 000	3 500	3 600	3 300
3 days	3 300	3 200	3 300	3 400	3 400
5 days	4 500	4 400	4 400	5 500	3 700
8 days	7 600	5 200	5 600	....	5 200
2.5 mos.	....	10 000	13 000	....	13 200
3 mos.	....	11 000	29 600	....	15 200
8 mos.	....	6 000	6 900	....	8 000

These show a progressive increase in color for three months, an increase greatest in the stoppered, unsterilized sample and least in the unstoppered, unsterilized bottle. That light plays little part is shown by the fact that the sample enclosed in a dark case has increased in color quite as much as the other samples.

A good deal of time was spent on these experiments, as it was supposed the behavior of water would be somewhat analogous. This was not found to be so, and the undesirability of drawing conclusions relating to color removal from anything but samples of natural colored water is evident. The preliminary experiments on tea did serve to indicate the general behavior of colloidal color in water and to familiarize the experimenter with the technique of his operations. Except for this, these experiments did not aid in the solution of the general problem.

2. ON WATER.

Experiments were made on twelve waters obtained from widely varying sources and localities. In every case, unless specified, all that was done was to send a current of electricity through the water in a U-tube, using platinum electrodes and 110 volts d. c. The color readings were taken at intervals on samples from each arm, and the results are given in Table 2. The discussion of only a few of the waters in detail will be attempted here, as Table 2 presents sufficiently detailed data upon which to base conclusions.

The water from Bridgewater was obtained from a morass in which large trees are growing and which has little or no drainage. The water was obtained soon after the spring rains. It contained a very high iron content, and was distinctly alkaline. There was a heavy brown precipitate in the bottom of the tube. The blank sample upon standing gradually acquired a heavy precipitate in the bottom and the color was reduced. When the color reached this state (oxidation of the iron and formation of the iron hydroxide — a gel*) 18 per cent. was removed by filtration through filter paper. There is no reduction of color when the original water is filtered, the change being due apparently to a change in the state of the iron content. The complex iron colloid is presumably oxidized to the hydroxide, which is insoluble.

The water from Mt. Auburn swamp was somewhat similar to the preceding, but its color was apparently almost entirely due to iron. Upon standing, precipitation took place after flocculation of the iron, and complete decolorization from an original color of 450 resulted in less than two months. This water, however, when fresh, was acid, and the color, therefore, carried a positive charge. For this very reason, the obedience to the laws of electrolysis as well as to those of cataphoresis was marked. The water has been especially mentioned on that account. This was the only water obtained which was acid, and was probably rather unusual for that reason.

In both the experiments noted above, there appears to be a

* Graham distinguished between the two conditions of colloidal solutions as follows: The term "sol" was applied to the liquid state, while to the solid, jellylike form he applied the term "gel." If one of the two components was water, the two corresponding colloidal forms were a hydrosol and a hydrogel (10). These terms are now in common use.

TABLE 2.

EXPERIMENTS OF WATER.

Hours.	0	15		20		25		35		40		50		65		90		150		200		Charge.		Acidity.	Alkalinity.	Iron.
Locality.	Color of Water, p.p.m., in +Arm and −Arm.																									
	+ −	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	p.p.m.	p.p.m.	p.p.m.
Arlington Reservoir ..	55					58	62			48	59											+		..	9	..
Artificial Pond.......	42									25	20												−	..	..	..
Bridgewater..........	1 020	580	230											340	230			230	220	160	150		−	..	12	17
Brockton............	76					60	76			60	75											+		..	..	23
Charles River........	70																	36	24				−	..	..	..
Hopkinton Reservoir	76					45	30					65	5										−	..	..	..
Lost Pond............	304									272	248							45	55	30	35		−	..	..	..
Lost Pond............	360	280	140											260	236									..	..	..
Marlboro, Crane Swamp......	245			240	210							350	160			470	40			450	0		−	..	2	0.75
Mt. Auburn..........	450									0	88							0	50			+		28	..	9
Mt. Auburn..........	232											8	25											..	..	..
Washington..........	110									28	48					33	49	40	15			+		..	..	..
Washington..........	96					20	96																	..	..	..
Ogeechee River.......	...					88	40	80	40							26	36						−	..	..	..

double movement, in the nature of a circulation, in each arm of the tube. The nature of this movement in the case of the Mt. Auburn water is shown in Fig. 1.* It will be noted that there are two positions of the top of the flocculated area, numbered 1 and

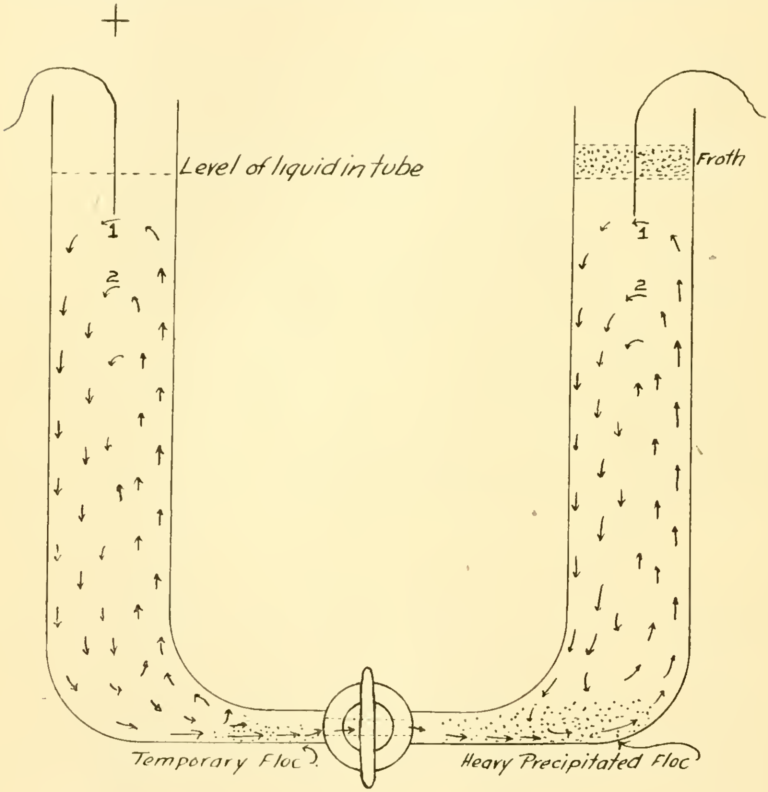


Fig. 1.

Diagram showing movement of positively charged colloid particles when subjected to cataphoresis.

2. At first, the flocculent particles appear to go nearly to the electrodes, but very soon there appears a zone of decolorized water around each electrode, and further movement takes place in the space below this zone. It is presumed that the intensity of the

* This figure shows also the colloid movements when an acid is added to a colored water.

electric field in this zone is strong enough to discharge the colloid particles when they approach its border, and so they flocculate and precipitate before reaching the electrodes. In this particular case all the colloid color particles should theoretically have moved from the positive to the negative electrode. Practically, the constriction in the tube was sufficient to hinder free passage, and certain particles being retained at the bottom took on, probably from contact, a negative charge and were drawn toward the positive electrode, where they were discharged. An alternating charging and discharging of particles in this way is the means which the writer has adopted to explain the frequent formation of floc in both arms of the tube, a phenomenon which occurs in many waters. With time, however, a complete neutralization of all charge on the floc was obtained, and precipitation resulted with reduction in color. The froth appeared only upon the negative arm (in the case cited above where the color is positive), and there was finally a gradual movement from the positive arm to the negative arm of the floc which accumulated in the bottom. All the precipitated particles which cause color will, if the process be carried far enough, be found in the bottom of the negative arm if the color is positive, and vice versa. (Fig. 1.)

If, now, an acid, such as concentrated HCl, be added even in minute amounts to an alkaline water such as that from Bridgewater or Marlboro, the hydrogen ion of the acid, being positive, reverses the charge on the colloid.* The reaction is very rapid,

* Since water (H_2O) dissociates into H + and OH − ions, it is probable that among other charges carried by the color colloids in water is a positive charge due to the H + ion of hydrogen. This ion may be in equilibrium with the H + ion in the water in such fashion that

$$\frac{\text{H + ion on colloid}}{\text{H + ion in solution}} = \text{a constant}$$

and similarly for the OH − ions if the adsorption law holds.

If, now, an acid, such as HCl, be added, which ionizes into H + and Cl − ions, the concentration of the H + ions in the water is greatly increased, and to maintain the constant relation indicated above, the H + ions on the colloids must also be increased. In this manner the colloid attains a stronger positive charge than it originally had. If there was only a negative charge, this will be discharged by addition of the H + ions to the water, and the colloid will adsorb the positive ion. By so much as it increases its positive charge, its tendency to move toward the negative electrode is also increased. That the colloid takes up an H + ion rather than a Cl − ion is due to selective adsorption.

Similarly, when a base is added to the water, the colloid may absorb the OH − ions (from, say, potassium hydroxide [KOH] which dissociates into K + and OH − ions), so that its negative charge is increased and it moves toward the positive electrode.

and the electric field set up so strong that a floc appears at once in both arms and moves toward the negative electrode, on which is deposited a brown, jellylike substance. In twenty-four hours the color of the Bridgewater water after addition of 0.025 per cent. $\frac{N}{1}$HCl was reduced from 840 to 0 in the positive arm and to 50 in the negative arm.

If, instead of an acid, the same amount of $\frac{N}{1}$KOH be added to the water, exactly the opposite reaction takes place, with slightly less rapidity. There is here movement in the same direction as the normal water exhibits in this particular case. The rule is general, however, that, irrespective of the original charge on the color particles in the water, the color will move toward and flocculate in the negative arm of the tube when an acid is added; and a reversal of this phenomenon will take place if a base be added. This is in exact accordance with Hardy's law regarding (7) the direction of movement of a hydrosol in an acid or alkaline fluid; namely, that "an immeasurable amount of free alkali causes the proteid particles to move against the stream, while in the presence of an equally minute amount of free acid, the particles move with the stream. In the one case, therefore, the particles are electro-negative and in the other are electro-positive."

What happens here is presumably that in the case where particles in the water are similarly charged to the acid or alkali which

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In the same way, when $Al_2(SO_4)_3$ (filter alum) is added to water, it dissociates into $Al+++$ and $3\ SO_4--$ ions. The color colloid by selection apparently tends to adsorb the $Al+$ ions. If the color colloid be negatively charged, then the positively charged Al ion serves to cause discharge, and there results flocculation and reduction of color through precipitation of the colloids. Moreover, there is formed hydrous aluminum oxide (aluminum hydroxide), which is a positively charged colloid. This also serves to neutralize the negative charge on the color colloid.

When the color colloid is positively charged, it will not be discharged by addition of alum, and decolorization will not be obtained by the means suggested above. When, however, $Al_2(SO_4)_3$ is added to water, aluminum hydroxide $Al(OH)_3$ is formed, which produces a heavy flocculant precipitate. This, settling more or less rapidly as a matte, gathers up the colloid particles by adsorption and enmeshing, and hence under the influence of gravity the color is carried down with the precipitate, and reduction in color is obtained.

In waters negatively charged, both processes would seem to be effective in color removal; discharge of the negative colloid by the $Al+$ ion and the hydroxide colloid, and the mechanical removal effected by the aluminum hydroxide. Under these conditions, color removal by alum is probably most rapid and effective. When the color colloid is positively charged, only the mechanical action of the hydroxide can be depended upon, and a larger amount of alum with possible overdosing is consequent.

is added, these particles merely have their charge intensified and the reaction takes place in the normal direction with greater rapidity. In case the particles are of opposite charge to the acid or base that is added, the ionizing effect of the acid or base is sufficient to discharge the charge on the particles and then to charge them oppositely to the original charge. Or the difference in potential may become sufficient and the flow of current strong enough to attract the color particles to the electrode of the same electric sign as themselves. If the difference in potential be great enough, positively charged particles may be attracted to the positive electrode, and thus the phenomena described may also be explained, on this hypothesis.

In most of the waters investigated there was a reduction of color in both arms of the tube upon cataphoresis. The reduction in the arm carrying the electrode of opposite charge to that on the particles was always less than in the other arm, and the froth always appeared on the arm toward which the colloid color particles moved. An explanation of the occurrence of froth has already been advanced. The cause for the reduction in color in both tubes is explained by two processes.

There is free oxygen given off at the positive electrode, and here the color particles (especially if they be negatively charged and so concentrated at that electrode) may be oxidized so as to lose their color. The most important cause, however, is supposed to be due to precipitation of the color colloids. There will be a reduction in color in the arm carrying the electrode of similar sign to the color colloids from migration of the colloids to the oppositely charged electrode. The slight reduction in color in the arm carrying the electrode of opposite sign to the colloids is due, as stated, to discharge in the vicinity of the electrode in this arm, and subsequent flocculation and precipitation. The flocculent particles are frequently not visible to the eye, but the reduction in color is usually evident, and after a time the accumulation of the precipitate in the bottom of the tube is conspicuous.

If all waters behaved in this fashion, with a reduction of color in both arms of the tube, the response of color in water to cataphoresis might not be considered entirely conclusive. Fortunately, two waters were found in which the color obeyed almost exactly

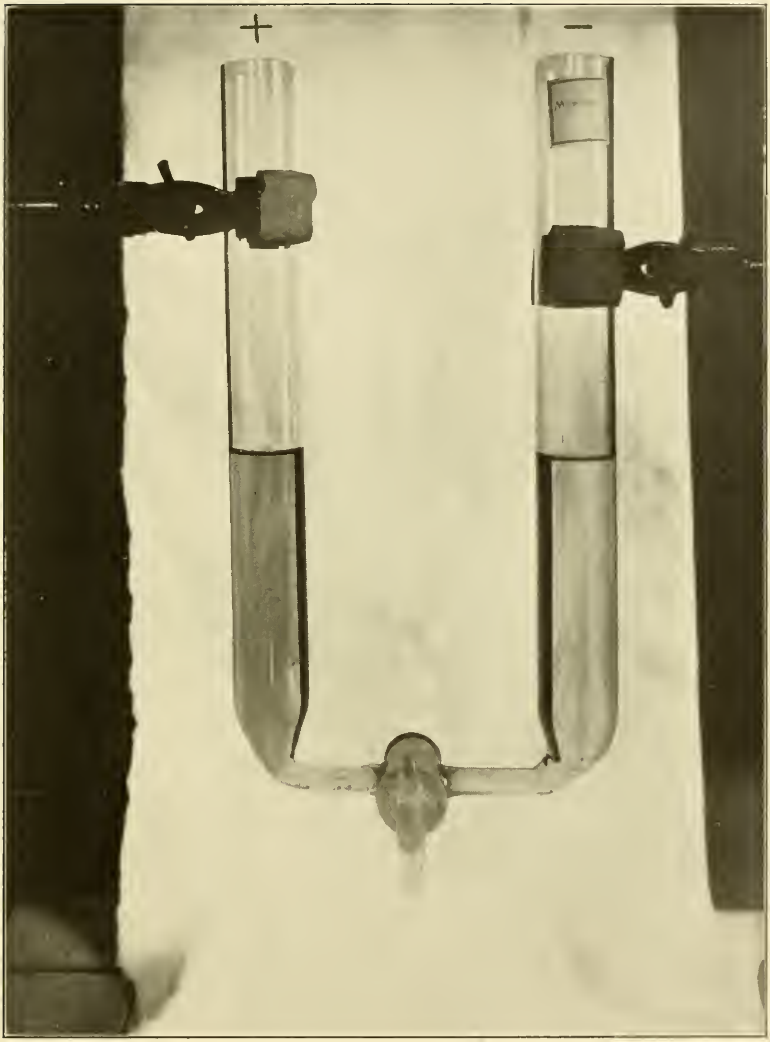
the theoretical laws of cataphoresis in colloid solutions. The Marlboro water is seen from Table 2 to have had an original color of 245. At the end of fifty hours the color in the positive arm had risen to 350, while that in the negative arm had decreased to 160, a mean of 255. After ninety hours, the colors in the positive and negative arms were 470 and 40 respectively, a mean of 255 again. After two hundred fifty hours, the colors were 450 and 0, a mean of 225, showing that the reaction was complete and precipitation had begun. The difference in color of the two arms of the tube is well illustrated by Plate III, taken at the end of two hundred fifty hours. The flocculated particles in the negative arm in the photograph are simply those few which the constriction in the tube prevents from passing to the positive arm.

It should be noted that not only is there a constant increase in color in the positive arm and corresponding decrease in the negative arm, but that the mean of the color in both arms is almost constantly very nearly that of the original water (245), as should theoretically be the case if there were no precipitation. If the current be kept on, precipitation will occur, a floc forming in the positive arm. There is doubtless some earlier flocculation not apparent to the eye, and this accounts for the decrease observed in the color of the mean after two hundred fifty hours.

That this water follows so closely the laws of cataphoresis is doubtless due to the fact that both alkalinity and iron content are almost negligible, a condition not found in the other waters examined. There were, therefore, no electrochemical reactions upon the complex iron colloids which interfered with the cataphoresis of the color colloids.

The waters from Hopkinton Reservoir and the Ogeechee River exhibited similar properties, an increase of color in the positive arm and a decrease in the negative arm. As the first of these waters is from Massachusetts and the second from Georgia, the colloidal condition of color in water was not of local occurrence. The color in these waters, however, was somewhat less stable than that in the Marlboro water, and the reduction in color in both arms soon appears with flocculation and precipitation.

The water from Lost Pond in Brookline is interesting because of the apparent change in character of the charge carried by the



Appearance of U-tube containing Marlboro water after being subjected to cataphoresis for 250 hours. Color in positive arm is 450, and 0 in the negative arm.

colloid color particles. The color is originally negatively charged, but after one hundred hours there has been a great reduction in color from neutralization and precipitation of the color colloids. It will be seen that at this point there is apparently a reversal of charge on the colloids remaining in suspension, and a consequent migration to and increase of the color in the negative arm. This reversal of color is explained in two ways. First, the normal negatively charged colloids have migrated to the positive electrode. Here most of them have been discharged and precipitated, but some have taken on a positive charge from this electrode and so move back toward the negative arm. In the second place, what little iron is present has become oxidized to the ferric state and become a positive colloid. Hence it tends to move toward the negative arm.

The water from Lost Pond showing these characteristics was obtained in the spring of 1916. Some water from the same place has been obtained this fall and does not show the variations noted above. This would indicate a more stable color and seem to show that the condition of the color in water varies at different seasons of the year.

In connection with the investigations outlined above, showing the colloidal nature of coloring matter in water, mention should be made of certain experiments made by Mr. M. C. Whipple in the Laboratory of Hygiene and Sanitation at Harvard University in 1913. These experiments consisted of placing in flasks leaf extracts and natural waters having colors ranging from 100 to 150. Over the tops of the flasks, sheepskin parchment was tied and the edges paraffined to make watertight. The flasks were then inverted with the lower ends submerged in beakers of distilled water. In no case did the color of the distilled water increase appreciably, although there was change in alkalinity content, showing that dialysis took place. The color, therefore, apparently existed in the condition of particles too coarse to pass through the parchment, for if the color had been due to substances in solution, it would have passed through by dialysis. Moreover, illumination under the Tyndall ray showed the presence of a large amount of colloidal substances in the colored extract, but none in the distilled water even after three hours. The colloidal

nature of coloring matter in leaf extracts, and in natural waters, is thus substantiated mechanically by these experiments, as well as indicated electrically by the investigations of the writer.

Change in Color with Storage.

Various waters were subjected to storage under varying conditions, the bottles being kept in the ordinary light of the laboratory.

The reduction of color by storage under room conditions was little unless the water contained a high iron content, which was easily brought into the ferric state and precipitated, as was the case with the Mt. Auburn water, and that from Bridgewater. In this event, the ferric hydroxide formed was a hydrosol and, upon contact or oxidation or by other means, was changed to the gel state and became a colloidal floc, when precipitation and reduction in color occurred.

In the open air, exposed to sunlight, there is always reduction of color in greater or less degree. The so-called bleaching action so frequently observed in the upper portions of reservoirs is possibly due in large measure to the action of the sunlight in breaking up the complex iron color colloid into some state in which its iron content may be oxidized and precipitated as described heretofore. The influence of sunlight upon waters of different degrees and state of color is well illustrated in the last three waters of Table 3. The Mt. Auburn water having an iron content of 9 p.p.m., which was readily brought into the hydroxide state even under room conditions, was completely decolorized upon standing in the open air. The Lost Pond water, having an iron content of 2 p.p.m. and color colloids of iron which were less readily brought into flocculation, was decolorized 66 per cent. in the open air. The Marlboro water, with very low iron content, 0.75 p.p.m., and color due largely to other than the iron colloids, shows practically no reduction of color upon exposure to light. This would indicate that bleaching action *per se* by sunlight was in no large degree responsible for color reduction, but operated only so far as it produced chemical changes affecting the stability of the complex color colloids.

The growths of algæ were pronounced in the Lost Pond water when exposed to sunlight, and did not occur under laboratory

TABLE 3.

Locality.	Condition.	Original Color.	Storage, Days.	Final Color.	Per Cent. Reduction.
1. Lost Pond	Filtered, not sterile.	360	58	360	0
2. Lost Pond	Filtered, not sterile.	360	58	360	0
3. Lost Pond	Filtered, not sterile.	360	58	380	–5.5?
4. Lost Pond	Incubated in dark at 37 degrees.	360	58	340	5.5
5. Mt. Auburn Swamp	Natural condition.	450	60	0	100
6. Bridgewater Swamp	Normal condition.	1 020	58	690	32
7. Mt. Auburn	Exposed outside window sill.	450	35	0	100
8. Lost Pond	Exposed outside window sill.	360	35	120	66
9. Marlboro	Exposed outside window sill.	245	35	240	2?

conditions. It is probable that these growths influence color removal, color colloids being retained on the gelatinous slime formed by them and so carried to the bottom.

Conclusions.

As a result of the experiments outlined above, the writer presents the following theory of the colloidal nature of coloring matter in water. The writer believes that the colloidal theory offers an explanation of many of the obscure and contradictory behaviors of colored waters toward coagulating agents and toward the general processes of decolorization. The theory that coloring matter in water is in part at least colloidal in nature is not new, but the investigations and elaboration of this theory presented herewith are believed to represent more advanced data upon the subject than have heretofore appeared.

Color in water in large part exists in the form of colloidal suspensions of ultramicroscopic particles or "suspensoids." Some of the color may be due to colloidal emulsoids. A small part of the color is probably due to non-colloidal material, organic acids, and neutral salts in true solution. The colloidal coloring matter, whether suspensoids or emulsoids, carries an electrostatic charge. This charge may be positive or negative, depending on the character and source of the water, and varying in different waters. Color in water is usually due to negatively charged colloidal material.

These charged particles are of such minute dimensions that, if allowed to remain quiescent under the influence of gravity alone, they would remain suspended for very long times. Being similarly charged, they tend to mutually repel each other and remain in suspension indefinitely, a tendency which is strengthened by convectional temperature currents, wind, etc.

Since these particles carry an electric charge, and are in colloidal suspension, they obey the laws of cataphoresis when an electric current is sent through a colored water. The particles are attracted to the electrode of opposite sign from the charge which they carry. There they are discharged, flocculate, and precipitate, with consequent reduction in color of the water. This type of reaction may be, and often is, modified by electrochemical

reactions, the reaction being theoretical only in those waters having little alkalinity or iron content.

When an acid is added to a colored water, the color migrates to the negative electrode. When a base is added, the color goes to the positive electrode. This is in accordance with the laws of Hardy outlined above.

Decolorization by Sand Filters.

Sand filtration has been found inadequate for the removal of color from highly colored waters. The degree of removal is very variable, depending on the water and the nature of the sand. A pure quartz sand (11) will remove little color, while sands containing much iron, aluminum, or manganese remove a large proportion of color. It is evident that the presence of iron and allied elements in a sand has an important effect upon the capacity of that sand for color removal. In general, experiment has shown that about one third the color in water can be removed by filtration through sand. That more color cannot be removed may be explained on the hypothesis that the colloidal particles of which it is composed are so extremely fine as to pass in large measure through the smallest capillary pores in the sand. It is possible also that the color colloids removed by filtration are of opposite charge to the filtering medium. The color not removed may not have come in contact with the filter material or may carry the same electrical charge.

Decolorization by Flocculation with Electrolytes.

This is perhaps the most general method of clarifying colored or turbid waters. Either alum or ferric hydroxide and lime are commonly used as coagulants. The general principle of these reactions upon the basis of the colloidal theory has been explained at length.* To summarize: It may be said that where most successfully used, the action depends upon the discharge of a negative color colloid by the positively charged ion of the coagulating agent and the positively charged hydroxide which is formed. The consequent neutralization of the charged color colloids results in flocculation, precipitation, and decolorization. This process is

* Footnote, page 91.

materially aided by the mechanical removal of the color colloids by the hydroxide floc which is formed.

When clarification is obtained with difficulty, the reason is frequently that the color colloids in the water bear a positive charge. Hence they are not discharged by the positive ion of the dissociating coagulant. Under such conditions, the removal of color is supposed to be entirely a mechanical process resulting from enmeshment and straining out of the color colloids by the precipitated hydroxide floc.

It is well known that a high alkalinity frequently causes difficulty in color removal. This is explained by the fact that the elements causing alkalinity are negatively charged. If, then, the color also be negatively charged, a correspondingly greater amount of positively charged coagulant ion and hydroxide will be necessary to cause neutralization and precipitation.

By Storage.

Some engineers believe that the removal of color in water consequent upon storage for long periods of time in large reservoirs is due to the bleaching action of sunlight. When decolorization occurs at considerable depths in the absence of light, oxidation has had to be adduced to explain the phenomenon.

That waters do become decolorized by storage is undisputed. It has been shown (1) that bleaching by sunlight is capable of removing color in water, but the writer doubts the competency of this process to explain the considerable color removal in reservoirs. If, as has been suggested in the foregoing statements, the color in water is largely due to particles in a colloidal state, the precipitation of such particles by storage is largely a matter of electrostatics.

The various streams tributary to a reservoir doubtless carry color particles having different charges. There is also more or less sediment in water, which generally is negatively charged. The mixture of all these variously charged particles in the reservoir probably tends to discharge certain of them, with consequent precipitation and decolorization.

Such, however, the writer believes to be only a minor cause of decolorization by storage. It was early shown by Hollis

(13) and later by Whipple (1) that the increase in color with depth in reservoirs is due primarily to the condition of the iron content; that at depths the iron is reduced and taken into solution; that upon rising to the surface in the spring, the iron is oxidized and adds to the color. That stagnation or storage will bring about an increase in color of the lower layers of the water which, given proper conditions of wind and temperature, may effect the upper layers, has also been shown by Whipple (1).

Notwithstanding this, there is in many reservoirs a decided decrease in color. What, then, is the cause of this decolorization, and how may it be explained by the colloidal theory? It seems probable that the iron content is the most important factor in this decolorization. Iron is important in sands for removing color; is a direct precipitant in the case of addition of electrolytes; is the factor upon which color removal by bleaching depends (see Table 3 and page 95); is the direct cause of color at the bottom of reservoirs; *in short, iron is probably the chief element influencing the presence and removal of color in water.* The iron probably does not exist in any such simple condition as the ferrous or ferric state. The iron content in color is supposed to exist in the form of certain organic compounds that are in colloidal state,—chemical compounds of extreme complexity. Due to many processes, of which oxidation and electrostatic neutralization by other colloids are the most active, iron is brought into the ferric state, in which case it exists as a hydrosol and will be precipitated by clay or any other negative colloid. Otherwise, some slow chemical change is brought about so that the complex iron suspensoid is broken up into constituent particles which may carry opposite charges and so mutually precipitate each other, or which may be discharged by other differently charged colloids present in the water.

In general, it may be said that most coloring matter in water, whether due to iron or not, is charged; and that the color suspensoids mutually repel each other, tending to maintain their suspensoid phase. In large bodies of water, however, agitation by convectional and wind currents, oxidation, algæ growths, etc., all tend to bring about contact between the color suspensoids and other colloidal substances in the water, many of which bear an opposite charge. There will tend to be discharge and neutrali-

zation. The particles will then flocculate and precipitate, and reduction of color will be apparent.

It has long been noted that, when certain turbid streams in the West carrying clay in suspension come into confluence with highly colored but clear rivers, there is sometimes a reduction in both color and turbidity in the effluent stream. This is readily explained on the hypothesis advanced above if the color and turbidity bear opposite charges. In the same way, prospectors in the West state that muddy turbid pools of water can be cleared well enough to drink from merely by moving about in them a piece of cactus stalk. This phenomenon, too, is explained by the colloidal theory, since the cactus sap is acid and hence carries a strong positive charge. The negatively charged clay is thus neutralized and precipitated.

The writer believes, therefore, that not only is color largely due to charged colloidal particles, but that the state and degree of iron in the water is the controlling factor, both as to the permanence of the color and its ease of removal. The latter is undoubtedly much influenced by the alkalinity, — a high alkalinity making for difficulty in color removal. The alkalinity increases the negative charges and also possibly makes for electrostatic stability of the complex iron suspensoids. The addition of alkali to water in the same way seems to operate to prevent neutralization of the electric charge on the complex iron suspensoid, thus maintaining the suspensoid condition and preventing flocculation and precipitation.

If any one conclusion is evident from these investigations, it is that generalized statements and rules regarding color in water and color removal cannot be made. Every water is in this respect a law unto itself, and the problem of color removal from any given water can be intelligently approached only after detailed study as to the nature and electrical properties of the color in that particular water.

There is great opportunity for further investigation along the lines of colloidal color in water, and that these investigations will undoubtedly prove helpful in the solution of the color removal problem is obvious. Such investigations, however, belong more properly to the water supply chemist than to the engineer. These

problems must be approached with an unbiased attitude, for hitherto preconceived ideas have militated against a fuller understanding of the subject. While it is probable that all color changes and removal in water are not wholly due to the colloidal properties of the coloring material, yet it would seem that the colloidal theory may be looked to for a more complete understanding of the nature of color in water, and for a more satisfactory solution of methods for its removal than now obtain.

Acknowledgment.

The results of the investigation and studies presented in this monograph are the outcome of experiments carried on in the Laboratory of Sanitation and Hygiene at Harvard University. The subject was first suggested to the author by Prof. G. C. Whipple, to whom is due very sincere appreciation for many courtesies extended, for advice and criticism, and for facilities and equipment for experimental work. The writer is also greatly indebted to Mr. M. C. Whipple, instructor in sanitary chemistry at Harvard University, for his constant aid, advice, and helpful suggestions; to Prof. E. B. Millard, of the Massachusetts Institute of Technology, for advice regarding certain details of the chemistry of the problem; and to Mr. George Broussard, for help rendered in the laboratory.

BIBLIOGRAPHY.

(1) *The Microscopy of Drinking Water.* George Chandler Whipple. New York, John Wiley & Sons, 1914.

(2) *The Decolorization of Water.* An informal discussion by G. C. Whipple, Allen Hazen, and others. Transactions American Society of Civil Engineers, Vol. XLVI, 1901.

(3) *Colloidal Theories, Applied to Colored Water, etc.* G. F. Catlett. Engineering Record, Vol. 73, June 3, 1916.

(4) *Colloidal Chemistry in the Removal of Color and Turbidity from Water.* G. F. Catlett. American Public Health Association, 1916.

(5) *The Physical Properties of Colloidal Solutions.* E. F. Burton. Longmans, Green & Co., London, 1916.

(6) *Floating Matter of the Air.* John Tyndall, London, 1883.

(7) *Conditions which Determine the Stability of Irreversible Hydrosols.* W. B. Hardy. Proceedings Royal Society, London, Vol. 66, 1899.

(8) *An Introduction to the Physics and Chemistry of Colloids.* Emil Hatschek. P. Blakiston's Son & Co., Philadelphia, 1913.

(9) *The Phenomena of Flocculation and Deflocculation.* E. E. Free. Journal Franklin Institute, Vol. 169, 1910.

(10) *The Chemistry of Colloids.* W. W. Taylor. Longmans, Green & Co., New York, 1915.

(11) *Woonsocket Water Works Reservoirs and Dam No. 3.* Allen Hazen. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 12, p. 32, 1897.

(12) *Decolorization of Water by Storage.* Ralph H. Stearns. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 30, 1916.

(13) *Relation of Color to Character of the Water.* F. S. Hollis. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 13, 1898.

(14) *The Physical Properties of Water.* Allen Hazen. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 17, 1903.

(15) *Removal of Coloring Matter in Water.* R. S. Weston. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 16, p. 160, 1902.

(16) *Report to the Massachusetts State Board of Health on the Metropolitan Water Supply.* Desmond FitzGerald, 1895.

(17) *The Effect of Storage upon the Quality of Water.* F. P. Stearns. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 5, 1890.

(18) *Electro-Chemistry.* Heinrich Danneel. John Wiley & Sons, New York, 1907.

(19) *The Technical Control of the Colloidal Matter of Clays.* H. F. Ashley. Technologic Paper 23, United States Bureau of Standards, 1912.

(20) *Salts, Soil Colloids, and Soils.* L. T. Sharp. Scientific American, Supplement No. 2101, April 8, 1916.

(21) *Problems in Smoke, Fume, and Dust Abatement.* F. G. Cottrell. Smithsonian Reports, 1913.

(22) *The Purification of Ground Waters.* R. S. Weston. Transactions American Society of Civil Engineers, Vol. LXIV, 1907.

DISCUSSION.

MR. GEORGE C. WHIPPLE.* I wish to express my appreciation of the careful work which Mr. Saville has done in connection with this investigation. I am glad we are going to have this paper spread upon our records, because it will show to the world that this Association is interested not only in the art of water supply, but in the fundamental science of water purification. It is a good thing once in a while to get a bath of science such as this. As Mr. Saville said, this is really a preliminary contribution to this subject. We have undertaken to solve a specific problem, and that is to find out some way to decolorize water

* Of Hazen, Whipple & Fuller, Consulting Engineers, New York; Professor of Sanitary Engineering, Harvard University.

without the use of chemicals, or, at least, to decolorize water without the use of such a chemical as alum. At the present time the only way which we know of decolorizing water is by the use of alum. That is the most satisfactory method, as Mr. Weston and as Mr. Johnson and others have already pointed out; and yet we all realize that this method has its shortcomings, and if we can decolorize water without the use of chemicals, or in some better way than at present, we shall accomplish something which is practical and worth while for the people of New England, where this condition is especially important. Therefore, I would regard this as a preliminary contribution. We hope that the results of other investigations now under way will be presented to you later.

Mr. George A. Johnson.* *Mr. President and Gentlemen,* — I have been highly instructed by Mr. Saville's paper and feel that there is very little I can contribute at this time. I am, however, somewhat curious to know about in what direction these studies may be practically applied to the decolorization of water on a large scale. Professor Whipple has expressed the hope that these studies may ultimately result in revolutionizing the existing methods of water decolorization, particularly with reference to the abandonment of the present methods. It would be very interesting to me if an indication could be given to-day as to how these new methods could be applied in practice, and about how their cost with equal efficiency would compare with the methods now in use. I am sure I shall look with a great deal of interest and anticipation for the results of future experimentation along these lines.

Mr. Francis F. Longley.† All of those present who are interested in problems of color in water, and in this part of the country most of us are so interested, will feel under obligation to the author of this paper for his clear presentation of the results of these experiments.

It is about fifteen years since the classic discussion before the American Society of Civil Engineers on the decolorization of water, led by Professor Whipple. Aside from the bare recognition of the existence of color in so great a proportion of our sur-

* Consulting Hydraulic Engineer and Sanitary Expert, New York.
† Of Hazen, Whipple & Fuller, Consulting Engineers, New York.

face supplies, the subject a short time before that discussion was a new one. The weak-tea color in our water supplies was taken as a matter of course. That discussion, however, was characterized by the unusual fullness with which the subject was treated. The facts there stated and the records of experiments there set forth have been quoted up to the present time, with little if any modification, as the best data available upon the subject of color in water.

Since then, the nature of coloring matter has not changed. The methods of observation of color so well thought out and established at that time are still the same. Our knowledge regarding its origin has increased, you might say, in volume, but not in weight, and our knowledge regarding its chemical construction as determined by the ordinary procedures of chemistry, organic or inorganic, has not made any measurable strides.

Our present conception of color in water was not touched upon in that discussion. Due mainly to the teachings and developments of physical chemistry, we to-day think of coloring matter in water in slightly different terms, and the studies described in the paper under discussion are of particular interest in this connection. We now look upon color, so to speak, with ultramicroscopic eyes. Instead of a true solution of organic matter, we see, for the most part, a suspension of ultramicroscopic particles; in other words, a colloidal suspension. We see the influence of gravity upon these particles offset by other forces, which may hold them indefinitely in suspension. And, as far as our studies go along these new lines of thought, we see these particles conforming in general, if not in every particular, to the physical and electrical laws of colloidal suspensions.

This is bound to stimulate new lines of thought for the treatment of water for the removal of color. We can hardly say we have progressed very far in that direction as yet, but our manner of thought towards this problem is changing, and we are beginning to give consideration to physical and electrical characteristics of the coloring matter to which no attention was paid a few years ago.

In the old paper above mentioned, the removal of the color from water by natural agencies and by chemical means was dis-

cussed. Professor Whipple and Mr. FitzGerald, referring to work done by the Boston Water Board, described what had been done to determine the laws governing the reduction of color by sunlight, which was recognized as one of the most potent natural agencies in decolorization.

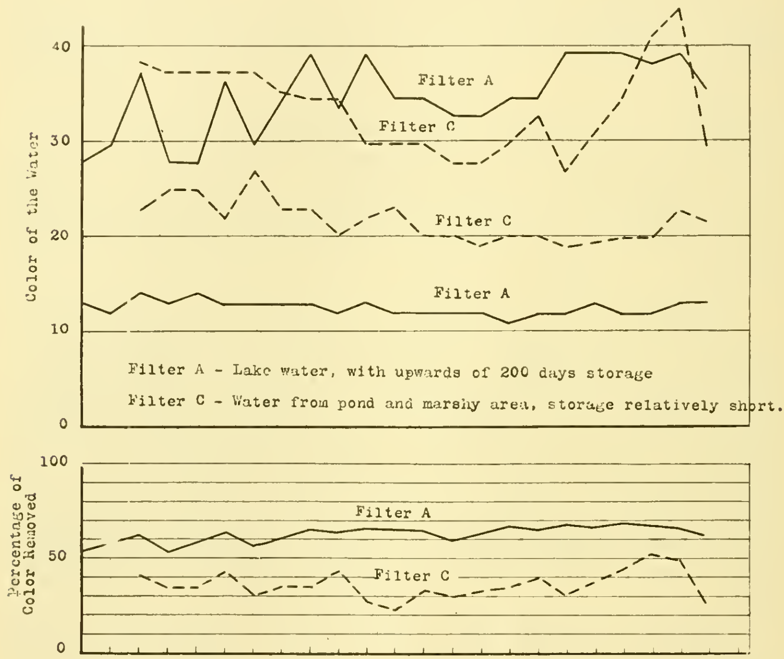
In the paper under discussion, the author makes the statement that "bleaching action, *per se*, by sunlight, was in no large degree responsible for color reduction, but only inasmuch as it produced chemical changes affecting the stability of the complex color colloids." It has always been recognized that the oxidation of iron aided materially in the natural removal of color. Whipple and FitzGerald both touched upon this. It seems to me it would be a mistake, however, to leave the impression that the oxidation of iron alone was responsible for the decolorization of reservoir waters.

Dr. Soper, in the discussion of fifteen years ago, emphasized the view that oxidation is the step by which color disappears in any process; that when carried to its furthest point, oxidation must destroy all coloring matter of organic origin. Extending his discussion of this view, he continued that atmospheric oxygen is too stable and inert to unite readily with organic matter, and hence aëration of water is of little direct use for the removal of color, but that ozone, which is a highly active oxygen, if brought into contact with water containing color, destroys and mineralizes it.

All this is possibly true. But why do we need to feel that stored water loses its color only by the *destruction* of the organic matter? Looking again through our ultramicroscopical eyes, it is reasonable to suppose that any action which will destroy the electrostatic or other obscure physical properties of these minute particles of color material in such a way as to permit the force of gravity to become effective upon them, and especially if this action increases the size of the particles, as by flocculation, will result in the removal of color by simple sedimentation.

There is no lack of possible agencies that might help in this action. Foremost amongst these is oxidation, and in this, iron plays an important part. There is the mixing of colored waters from different sources, and with possibly different electrical charges,

the mixing of colored waters with the stored waters in which action of this sort has already advanced, and the addition of ground water. There is the growth of algæ, with the accompanying formation of oxygen. There is the action of bacteria, which are at times thought to produce a fermentation of the organic matter.



Time in Days.

Fig. 2.

Color removal by sand filters from two waters of different periods of storage.

There is adsorption. And there is sunlight, with its well-known powerful actinic effects.

One could perhaps speculate much further as to possible factors in this. We do not yet know enough about any of these to conclude categorically that this factor does and that factor does not affect the final results, and in what degree.

Whatever the steps in the process, which are so obscure that

there seems but small hope of ever defining them and measuring their effects, it appears from the available evidence that a part, at least, of the colloidal suspension that produces the effect of color in water increases in effective hydraulic value and probably in size under the influence of the various natural agencies, and in the course of time finds its way to the bottom of the reservoir.

In this final result, the writer believes his views do not differ materially from those of the author of this paper.

Some results obtained from two small sand filters in a recent investigation lend strength to the view that the ultramicroscopical particles in a stored water are larger than those in a similar water of about the same color, but which has not had the benefit of much storage. These results are shown on the accompanying diagram (Fig. 2).

These two slow sand filters were identical in design. They were operated at the same rate, namely, 5 mil. gal. per acre per day. They were operated on the same drainage area, at the same time, and on waters having substantially the same initial color. All conditions were practically identical for the two filters, except the length of time the water stood in storage. Water applied to Filter A was taken from a lake of about 250 acres area, with a draft of about 6 mil. gal. per day. The period of detention was upwards of two hundred days. Water applied to Filter C was taken from a small pond and marshy area. The period of detention was not known, but it was irregular and relatively short.

The percentage removal of color from the stored lake water was nearly twice as great as from the other. This was due to some important difference in the physical condition of the particles of the colloidal suspension, and the most obvious inference is that they were larger in the stored water.

Perhaps the commonest method of distinguishing a colloidal from a crystalloidal form of matter is to determine its rate of dialysis through a suitable membrane. Various membranes may be used for this, the best probably being goldbeater's skin. Membranes of sheepskin and of collodion are sometimes used, but the commonest and most convenient membrane is parchment paper. It cannot be said that matter in the colloidal state will not pass through such a dialysing membrane in any degree, but

it is true that true crystalloids in solution pass through readily, and that the rate of passage of the colloid is so very slow as to make this an interesting means of classification. The author makes reference in his paper to some experiments made along this line by M. C. Whipple, and the writer has record of other experiments of this kind that he thinks interesting enough to present.

Some samples of water, colored with various substances, were put through a dialysis test with the results shown on the accom-

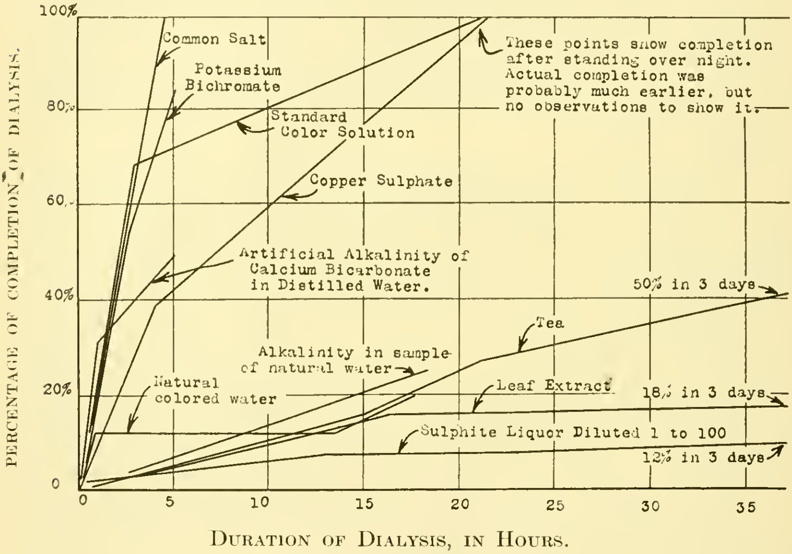


FIG. 3.

Diagram showing difference in rate of dialysis of various coloring substances.

panying diagram (Fig. 3). The true crystalloids such as sodium chloride, potassium bichromate, copper sulphate, and others, passed through completely within a period of a very few hours. The action was rapid from the start.

On the other hand, the coloring matter of natural water, of tea, of leaf extract, and of sulphite liquor passed through only in small degree and very slowly. In twelve hours not more than 15 per cent. of any of these colors had passed through the mem-

brane. In twenty-four hours not more than 30 per cent., and in most cases not more than 20 per cent., had passed through. In three days about 50 per cent. of the coloring matter of tea had passed through, but not more than 20 per cent. of the color of raw water, leaf extract, or sulphite liquor had passed through.

In another experiment of the same kind, some 10 or 12 per cent. of the color passed through in one hour, and only 25 to 40 per cent. had passed through in three days.

Mr. Lounsbury, at Superior, using fish bladders as a dialysing medium, found that the sometimes highly colored water of Superior, which is heavily charged with iron, passed only a small proportion of its color in several weeks, whereas the coloring matter of tea passed through much more rapidly.

There is evidence that the organic matter in water is sometimes intimately combined, not only with dissolved iron, but also with the alkalinity. The amount of alkalinity in the form of calcium carbonate theoretically necessary to combine with 100 lb. per million gallons of aluminum sulphate is about six parts per million. It has been found at times that if a dose of aluminum sulphate be added to a colored water in the quantity computed to use up all the alkalinity on this basis, and to make the water acid, it does not always become acid, but retains a small alkalinity. Observations of this sort have suggested the inference that there is alkalinity present combined in some way with the color so that not all of it responds to the usual indicator, and that the addition of the mineral acid radical of the coagulant results, first, in combination therewith of the proper amount of available alkalinity, and, second, some alteration of the delicate balance of the dilute solution, with more alkalinity splitting off from the weak acid color in a form that the indicator will detect. Instead of the six parts per million that is indicated by the conventional formulæ for the reaction, alkalinity reduction is often found to be five, four, and even as low as three parts per million for each 100 lb. per million gallons of aluminum sulphate. This phenomenon has been noted often, and has sometimes been explained by absorption of some of the aluminum sulphate by the color or the turbidity in the water, or perhaps by incomplete chemical reaction in the presence of low alkalinity. The evidence

as to the exact cause is not convincing, but it is interesting to note the behavior of the alkalinity upon dialysis.

It was inferred that the passage through a dialysing medium of the alkalinity in a naturally colored water would be less rapid than in the case of an artificial bicarbonate alkalinity. This was tried out and found to be true. Artificial alkalinity of about fifty parts per million was made up in distilled water. Upon dialysis, some 30 per cent. passed through in one hour and 50 per cent. in five hours. A colored natural water subjected to dialysis under practically identical conditions passed only 25 per cent. of its alkalinity in eighteen hours, indicating a much slower action. Violent and prolonged boiling seemed to break up, to some extent, the combination between the organic matter and the alkalinity so that 70 per cent. of the alkalinity of a sample of raw water so treated passed the dialyser in seven hours.

The removal of color by means of aluminum sulphate is influenced by the amount of alkalinity in the water. For a given water there is an alkalinity comparatively low and not many points above the neutral point where the coagulation seems to be best.

The difference in behavior of natural color and of the color of true crystalloids, and of natural and artificial alkalinities when subjected to this treatment, is conspicuous, and affords an additional bit of convincing evidence as to the nature of the coloring matter in water.

The use of aluminum sulphate in connection with water filtration is the most common means of artificial removal of color. The author has pointed out that this occurs, in general by the discharge of a negative color colloid by the positive ion of the coagulant, aided by the mechanical removal effected by the hydroxide of the coagulant. As he further indicates, the action may not always occur in this way, and different waters vary a great deal in their response to this treatment.

Some interesting records of the relationship between coagulant required, and the color thereby removed, are presented in a diagram (Fig. 4). As a basis for comparison, there is also given the line used by Professor Whipple fifteen years ago to show the amount of aluminum sulphate required to decolorize waters of

moderate alkalinity, which line has been much used and quoted since then. All of these lines are, of course, average lines, and the originals show the plotted points scattered widely on both

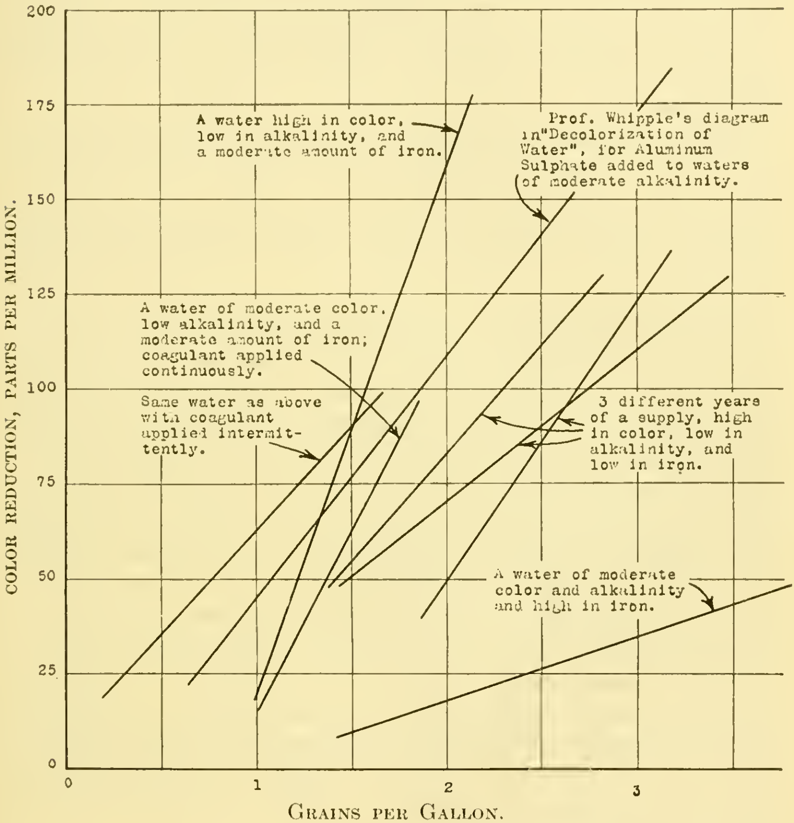


FIG. 4.

Diagram showing quantity of aluminum sulphate required for the removal of color from various waters.

sides. They serve, however, to illustrate the difference in the nature and magnitude of the action upon waters of different characteristics.

The extreme line of this diagram is significant as showing the

resistant nature of a high iron content in this water. The experimenter said of this: "The iron is precipitated with difficulty by ammonia. At times it is found that the iron would all be precipitated with the first addition of ammonia, and at other times it was necessary to repeatedly acidify and make alkaline in order to precipitate the iron. With this water it is not always possible to obtain the sulphocyanide test even when iron is known to be present."

It does not seem to be always true, however, that the presence of iron causes difficulty in the removal of color. Three of the lines on the low side of the diagram represent waters containing moderate amounts of iron, yet they present no particular resistance to the action of the coagulant as does the case mentioned above.

These comparatively recent ideas regarding the nature of color should serve to stimulate further study aimed at improvements in methods for its removal. Can we, for instance, discover effective means of action not heretofore recognized which will enable us to dispense with the use of aluminum sulphate? It would be highly desirable if we could, for while this chemical has served us well, and, in fact, has been practically indispensable in the treatment of many supplies, it is not an unmixed blessing, and in certain respects those supplies might be more satisfactory if other means could be found for their preliminary treatment. And what artificial forces can be used to bring about mutual attraction amongst these ultramicroscopic particles, resulting in flocculation, increase in subsiding value, and consequent removal by sedimentation? We already know well that flocculation following the application of aluminum sulphate is materially aided by the right amount of agitation, and this knowledge has been profitably applied in practice.

Can any of the methods suggested by the interesting laboratory results recorded in the paper be applied successfully on a large scale? Can they be speeded up sufficiently to make them practicable? Can they be accomplished with reasonable economy? Unfortunately, the laws involved are not so simple and so easily understood as the conventional physical and chemical laws that govern the actions as we have understood them in the past, but

nevertheless the field is a large one and an interesting one, and these and other similar questions wait for an answer. As it becomes more clearly recognized that profound actions hinge upon obscure factors such as the concentration of ions of one sign or the other, or the electrostatic charges upon the colloidal particles that produce the color effect in water, and as the advance guard of scientists connected with our public health and water supply questions succeeds in devising means for the convenient measurement and control thereof, we may hope for interesting developments in the direction of the decolorization of water.

Mr. Robert S. Weston.* This exceedingly and wonderfully clear-headed paper, which I think we will all read with great care when it is published in the Journal, suggests to our minds great possibilities in the way of color removal. As I have listened to the paper this afternoon I have been impressed with the way that the experimental data accord with our experience. I feel that this is just the beginning of something which will, perhaps, lead us beyond our present not entirely satisfactory methods.

Mr. Saville. I wish to say that this matter has been emphasized, both by Professor Whipple and myself, as being in the nature of a progress report. We believe that every bit of experimental evidence that we can get on any scientific subject, and we do believe that color removal is a scientific subject, is of value; and what we have to present just now is, perhaps, more in the nature of suggestions to water-works men. In reading the paper they may be able to apply some of the suggestions there presented to their own work, and then later, if our own experiments show a commercially applicable method, perhaps we shall have something more definite to say.

The President. I think that some of the members will appreciate Mr. Saville's offer to have us send in for experimental work any highly colored waters we have.

Mr. Melville C. Whipple † (*by letter*). The studies in which Mr. Saville has been engaged are particularly interesting and attractive to experimenters in water-works problems. He has applied a unique method to his work, and has described results

* Of Weston & Sampson, Consulting Engineers, Boston, Mass.

† Instructor in Sanitary Chemistry, Harvard University.

which add materially to our knowledge of the true nature of color in water.

It occurred to the writer that the presence of CO_2 might exercise some effect on the migration of colloidal coloring matter in the electrical system described by Mr. Saville. Accordingly, experiments were made upon waters from widely separated localities, first, by simply passing a current through the U-tube, and, second, by passing a current and also a slow stream of CO_2. The results are given in the table below. These tests were not many in number and were undertaken primarily to suggest further lines of research.

Color readings in parts per million on the platinum scale are given for the water before the experiment and for the water in the positive and the negative arms of the tube after the experiment. It should be borne in mind that coloring matter found in the positive arm carried a negative charge, and that in the negative arm a positive charge. The percentage that the reading in the negative arm was of that in the positive is also given, and it is to these figures that attention is directed. A control experiment was also made by passing a stream of CO_2 through the water for twenty-four hours. A negligible reduction of color resulted.

TABLE SHOWING EFFECT OF PASSING A DIRECT CURRENT THROUGH COLORED WATERS, AND ALSO OF PASSING A CURRENT AND A STREAM OF CO_2.

Source of Sample.	Original Color.	Color without CO_2.			Color with CO_2.		
		Pos. Arm.	Neg. Arm.	% Neg. was of Pos.	Pos. Arm.	Neg. Arm.	% Neg. was of Pos.
Black River, Watertown, N.Y.							
27-hour experiment	70	82	75	91	80	48	60
27-hour experiment	70	72	67	93	68	44	65
Exeter River, N. H.							
27-hour experiment	140	172	120	70	168	96	57
51-hour experiment	140	182	120	66	168	66	39
Lake Kilby, Virginia							
27-hour experiment	60	60	45	75	48	0	0

The following conclusions have been deduced from the results in the table.

1. The color colloids in all three waters showed negative characteristics when a current was passed *without* CO_2. Mr. Saville has demonstrated that this is the case with the majority of natural colored waters, particularly those which have had a period of storage.

2. The Black River water exhibited very feeble negative properties; the other two were distinctly negative in character. These results offer further evidence of the differences in the behavior of coloring matter which may be encountered in waters from different sources.

3. The addition of CO_2 increased the negative properties of the colloidal coloring matter in all three waters. The effect was most pronounced in the case of the Lake Kilby water, which showed absolutely no color in the negative arm of the tube after the experiment. In other words, all the color remaining carried a negative charge and migrated toward the positive pole. The effect of adding CO_2 to the other two waters was not as pronounced, but nevertheless was decided.

In what way, then, did CO_2 react to bring about a decrease in the percentage of positively charged coloring matter, and why was this decrease so much greater in the case of Lake Kilby water? The answer to these questions cannot as yet be given with entire confidence in the accuracy of their statement, but when it is considered that CO_2 dissolved in water bears a negative charge in the ionic condition, it is reasonable to suppose that it may enter into loose combination with, or be absorbed by, certain kinds of colloidal coloring matter, and that in so doing it imparts negative electrical properties to such colloidal particles. The extent to which this phenomenon occurs may well depend upon the nature of the colloids present. Some of them may not be susceptible to any such action. Others may behave in the manner of amphoteric substances and become positively or negatively charged according to the condition of the solution. Thus the Lake Kilby water may have contained colloidal coloring matter which was in part positively charged in the absence of CO_2, but which took on a negative charge in the presence of CO_2.

These experiments in some aspects have a bearing on practical matters. The Black River and Lake Kilby waters are both subjected to mechanical filtration with the use of alum as a coagulant. The latter water allows a high percentage removal of color per unit of alum used, and ordinarily exhibits very rapid coagulation with the formation of a coarse floc. In the experiments without addition of CO_2, the coloring matter of this water manifested negative properties. Inasmuch as the colloidal alum precipitate is positively charged, the negative charge on the color colloid is neutralized and the precipitation of both substances occurs.

The water tested in the laboratory was of necessity collected many days previously, and was practically devoid of CO_2. When CO_2 was added to Lake Kilby water, the negative properties were greatly increased, as previously mentioned. Such a condition would greatly augment the formation of a good coagulum with the positively charged aluminum colloid. As received at the filter plant, the water from the lake contains a very large amount of CO_2, and so in the light of the experiments described would conform to ideal conditions for coagulation.

The Black River water, on the other hand, frequently manifests very poor coagulation and may be classed as a difficult water to treat. Reference to the table of experimental results indicates that very weak negative properties were exhibited in the absence of CO_2. The charge on the colloidal particles of coloring matter in such a water would be neutralized only to a limited extent by the positively charged aluminum colloid, and as a result poor coagulation might be expected.

In the presence of CO_2, this water possessed stronger negative properties, but could not be compared with Lake Kilby water in this respect. Furthermore, as received at the plant for treatment, the water from the Black River does not carry anything like the content of CO_2 found in the water from Lake Kilby. To summarize, we have on the one hand a water distinctly negative in the absence of CO_2, entirely negative in the presence of this substance, carrying large amounts of CO_2 at its source, and giving satisfactory coagulation; on the other hand, a water weakly negative in the absence of CO_2, distinctly negative in the presence of CO_2, carrying only moderate amounts of this substance at its source, and offering difficulties in the way of coagulation.

This conception of the functions of CO_2 in intensifying the negative properties of color colloids is drawn from a very few experiments, but in the writer's mind it seems to fit the facts as observed. It is substantiated further by practical tests at certain filter plants where the addition of chemicals has been varied from standardized procedure in a manner that gives superior results at a lower cost.

In the *Engineering Record*, June 3, 1916, Mr. George F. Catlett described some experiments made at the Wilmington, N. C., mechanical filter plant. The application of his studies to the treatment of the water there resulted in marked improvement and an economy of over 50 per cent. in the use of chemicals.

The raw water at Wilmington is taken from the northwest branch of the Cape Fear River, a stream which drains a large area of cypress swamps and which possesses a very high color, 150 to 300 parts per million, and very little turbidity. Such is the character of the water at the plant at low tide. At high tide, water sets back from the main stream a short distance below. This stream is highly turbid and very low in color. As a consequence of the mixing, the raw water at the plant may contain at times of high tide from 30 to 50 parts per million of turbidity and perhaps 150 parts of color. Alum is used as a coagulant, and soda or lime to restore deficient alkalinity. The raw water seldom has more than 5 to 8 parts per million of alkalinity.

Under the old system of treatment, both the alum and soda were added before the water passed to the coagulation basins. The results were uncertain and unsatisfactory, the final effluent of the plant usually having a color of 40 to 100 parts per million, and containing more or less coagulant in a colloidal condition. Under the modified system, the alum is added as previously, together with just enough soda to allow an excess of $\frac{1}{4}$ grain per gallon of alum. The water is thus overdosed as it passes through the first basin. In the second basin, enough soda or lime is added to insure a final alkalinity of 10. Good coagulation and sedimentation result from the new procedure, the final effluent of the plant has a color of less than 10 and is free of colloidal particles of coagulant, and the alum has been reduced in amount from about 4 grains per gallon to 2 grains.

In the light of the experiments at Harvard, the Wilmington procedure is a rational one and the results obtained are consistent with the theories set forth in some of the preceding paragraphs. If alum is added to the water in sufficient amount to leave a slight excess, there will be liberated and left free in the water the maximum amount of CO_2 from the reaction between the alum and the alkalinity. On the other hand, if alkali is added with the alum, in order to maintain an alkaline condition, then part, or all, of the CO_2 will become fixed as bicarbonate.

It has already been shown that free CO_2 carries a negative charge on its ions and when present in a colored water tends to increase the negative properties of the color colloids. Consequently, when the colloidal particles of aluminum hydroxide are formed, their charge is neutralized by that of the colloidal color particles. Precipitation and flocculation are stimulated and we have efficient removal of color and turbidity. Mr. Catlett stated in the article referred to that the coloring matter of Wilmington water bears a positive charge, but in a later paper* says that experiments show it to be negative. From the standpoint of this discussion he has succeeded by means of the modified method of chemical treatment in preserving, and probably in intensifying, the negative properties of the Cape Rear River water until such a time as coagulation is complete.

Other experiments made at Wilmington in connection with the subsidence of turbidity also illustrate the negative properties imparted to water by CO_2. When lime was added to a water containing 160 parts per million of turbidity and 60 parts of color, in an amount sufficient to neutralize the CO_2, a very few hours sufficed to effect almost complete subsidence of the turbidity. Untreated water showed very slow precipitation. The experiments were conducted in jars, and no alum was added. Colloidal clay particles carry a negative charge. The presence of CO_2 tends to increase the stability of these suspensoids and prevents them from coming together to form aggregates. Removal of CO_2 decreases the stability, and when lime is used for the purpose it is also likely that there are formed small amounts of insoluble substances of a positively charged colloidal nature. These would

*American Public Health Association, Cincinnati Meeting, October, 1916.

neutralize the negative charge on the clay particles and thereby induce subsidence.

Valuable application of this method of treatment might be made in the case of a highly turbid, slightly colored water, lime being added before the alum. If a large amount of color is present, it is impracticable. The method would interfere with color removal just as it formerly did at Wilmington, when soda was added and the CO_2 fixed before coagulation was complete. In such a case, if turbidity persisted after color removal, lime might be added to the settled or partially settled water and the period of flow through the coagulation basins extended. This has been proposed at Wilmington.

The practice of "overdosing" colored water with alum was first brought to attention at Springfield, Mass., by Mr. Elbert E. Lochridge, and the method practiced there has been described by him in the *American Journal of Public Health*,* November, 1914. The water at this plant is filtered through slow sand filters after a long period of coagulation and sedimentation in a large natural basin. It was found that a greater reduction of color was obtained, with a smaller amount of alum, if alum was added in excess of the alkalinity for a period, and then discontinued for a period. This water has very little turbidity and a low alkalinity.

Various theories have been set forth to account for the improved results at Springfield. To the writer it seems that this must be due in a very large measure to the fact that the "overdose" of alum liberates a greater amount of CO_2 than the normal dose. This intensifies the negative character of the water and accelerates the precipitation of the colloidal aluminum compound. The charge carried by the excess alum may also stimulate this neutralization of colloidal color charges. Once the phenomenon of flocculation is actively started, the precipitation of the excess alum by the untreated portion of water which follows is rendered certain. The amount of CO_2 present during this secondary precipitation is of course much greater than would be the case if the amount of excess alum was added directly to raw water. Consequently, conditions are more favorable for coagulation. The alkalinity necessary for the final effluent is supplied by the water

* See also JOURNAL N. E. W. W. A., XXXI, p. 48.

which is not dosed directly. Only a small part of its bicarbonate alkalinity is neutralized by the excess alum in the dosed water, the balance imparting a permanent alkalinity to the water. There is no neutralization or " fixing " of the free CO_2 when alkalinity is supplied in this way, as the natural lime salt is already in the form of bicarbonate.

Problems of coagulation and color removal have continually vexed water-works men in connection with filtration. Some of these have been solved locally, but our basic knowledge of the true nature and properties of coloring matter has been too meager to allow the fomulation of practice which could be broadly applied. Laboratory experiments on the " dosing " of water have been made and repeated by the hundreds. They have served chiefly to stimulate speculation and theory, but their divergent results have confused rather than clarified conceptions regarding coloring matter and coagulation. It is evident that physical chemistry is really going to give us some definite information on these subjects. For that reason, it is important that the colloidal theory of coloring matter be put to every form of experimentation which our ingenuity may devise. Work in this field is attractive and worth while.

Mr. Saville (*by letter*). The chief aim of the present paper has been to present certain ideas relating to the nature of color in water, in the hope that water supply engineers and chemists would be able to obtain suggestions from which they might interpret the behavior of certain waters toward decolorization processes. The discussion by Messrs. Longley and Whipple is therefore particularly gratifying, in that they have each explained, on the basis of the colloidal theory, results obtained in the treatment of colored waters, the interpretation of which would otherwise be obscure.

Mr. Longley presents the interesting fact that of two waters of equal color, that which has been stored longest will, according to the colloidal theory of color in water, contain the largest color colloids. Hence it will be more readily decolorized by filtration than the other water stored for a shorter period. The experiments described on dialysis of colored waters and artificial colored extracts seem to substantiate the author's conclusions.

Mr. Whipple has supplemented the investigations of the author by studies of colored waters subjected to cataphoresis in the presence of CO_2. His observations are of particular importance in that he is enabled to explain on the basis of the colloidal theory certain results in color removal obtained by somewhat unusual procedures at both Wilmington, N. C., and Springfield, Mass.

These cities have used alum in removing color from their water supplies, but in both instances the process of treatment with alum has been novel and specialized. It was known that the ordinary methods of dosing with alum did not effect a satisfactory removal of color, and resort was had to special methods of treatment. It was not known (although it was inferred at Wilmington) just why the modified treatment worked successfully. The author believes that Mr. Whipple has satisfactorily explained this upon the colloidal theory and shown that the methods used are logical and proper for the particular waters in question.

It is by the acquirement of such definite knowledge as to the *why* of color removal practices that the colloidal theory offers the most immediate results. After further information has been gathered as to the cause and nature of color and the reactions involved in its removal, we may then hope to devise some new methods, or modifications of existing methods, of color removal which will be more satisfactory than those now used.

PROCEEDINGS.

December Meeting.

Hotel Brunswick, Boston, Mass.,
Wednesday, December 13, 1916.

President Sullivan in the chair.

The following members and guests were present:

Honorary Members.

Edwin C. Brooks.
R. C. P. Coggeshall.
Albert S. Glover.
Frank E. Hall. — 4.

Members.

S. A. Agnew.
L. M. Bancroft.
A. E. Blackmer.
J. W. Blackmer.
George Bowers.
J. M. Caird.
George Cassell.
J. C. Chase.
F. L. Cole.
J. M. Diven.
C. H. Eglee.
E. D. Eldredge.
G. F. Evans.
S. F. Ferguson.
F. L. Fuller.
Patrick Gear.
H. T. Gidley.
F. J. Gifford.
H. J. Goodale.
J. M. Goodell.
R. A. Hale.
R. K. Hale.
L. M. Hastings.
T. G. Hazard, Jr.
D. A. Heffernan.
Charles R. Hildred.
J. L. Howard.
A. C. Howes.
G. A. Johnson.
W. S. Johnson.
E. W. Kent.
Willard Kent.
G. A. King.
J. J. Kirkpatrick.
John Knickerbacker.
F. F. Longley.
E. J. Looney.
P. J. Lucey.
W. J. Lumbert.
Hugh McLean.
H. V. Macksey.
W. E. Maybury.
John Mayo.
Frank E. Merrill.
William Naylor.
T. A. Peirce.
H. G. Pillsbury.
E. W. Quinn.
G. A. Sampson.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
C. W. Sherman.
Sidney Smith.
G. H. Snell.
W. F. Sullivan.
W. C. Tannatt, Jr.
C. N. Taylor.
Milton Thorne.
A. H. Tillson.
E. J. Titcomb.
C. H. Tuttle.
W. H. Vaughn.
R. S. Weston.
L. J. Wilber.
F. B. Wilkins.
G. E. Winslow.
I. S. Wood.
M. B. Wright. — 70.

Associates.

Harold L. Bond Co., H. H. Sinclair, F. M. Bates.

Builders Iron Foundry, F. N. Connet, A. B. Coulters, G. H. Lewis.

Darling Pump and Mfg. Co., Ltd., H. A. Snyder.

Eddy Valve Co., H. L. Prescott.

Fire and Water Engineering, Fred Shepperd.

Hersey Mfg. Co., Albert S. Glover, J. H. Smith.

Lead Lined Iron Pipe Co., T. E. Dwyer.

Macbee Cement Lined Pipe Co., J. P. MacBride.

H. Mueller Mfg. Co., G. A. Caldwell.

National Meter Co., J. G. Lufkin, H. L. Weston.

National Water Main Cleaning Co., B. B. Hodgman.

Neptune Meter Co., H. H. Kinsey.

Pitometer Co., E. D. Case.

Pittsburgh Meter Co., J. W. Turner

Rensselaer Valve Co., C. L. Brown.

A. P. Smith Mfg. Co., F. L. Northrop.

Thomson Meter Co., E. M. Shedd.

Union Water Meter Co., E. K. Otis.

Water Works Equipment Co., W. H. Van Winkle.

R. D. Wood & Co., H. M. Simons.

Henry R. Worthington, E. P. Howard, Samuel Harrison. — 27.

Guests.

Rhode Island.

East Greenwich, James Kinloch.

Massachusetts.

Attleboro, R. Bevenage.

Cambridge, Thorndike Saville.

Holyoke, P. E. Gear.

Northampton, C. P. Houghton.

North Andover, R. H. Ellis.

Dominican Republic.

Santiago, W. J. Ryan. — 7.

In response to a call by the President, Commissioner Donnelly, of Lowell, opened the after-dinner exercises by singing several songs, which were enthusiastically applauded by the members, who, at the suggestion of Mr. Macksey, further expressed their appreciation of Mr. Donnelly's performance by a rising vote of thanks.

The Secretary presented applications for membership, properly endorsed and recommended by the Executive Committee, from the following:

Thorndike Saville, Cambridge, Mass., instructor in geology and sanitary engineering, Harvard University; Richard H. Ellis, superintendent Board of Public Works, North Andover, Mass.; Charles L. Crosier, Boston, Mass., assistant in civil engineering at Massachusetts Institute of Technology; Ernest H. Rigg, Woodbury, N. J., chairman of Water Committee, City Council;

James Menzies, Sydney, N. S., superintendent Water Works, city of Sydney.

On motion of Mr. Coggeshall, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared elected members of the Association.

Mr. R. A. Hale. I want to call the attention of the members to a new publication which has just been issued by the Geological Survey, on the surface waters of Massachusetts. It has been compiled by C. H. Pierce and H. J. Dean, of the United States Geological Survey, in coöperation with the state of Massachusetts. It comprises a volume of about 430 pages, giving the flows of all the principal rivers and the records of some 35 gaging stations. The Lowell period is from 1848 up to the present time. We have the flow of the Merrimack River at Lawrence for thirty-five years, and the Deerfield and Concord rivers, and a great many other rivers are covered for different periods. It will be of great value to water-works, sanitary, and hydraulic engineers in determining the probable water supplies and the flow of the streams.

Mr. Pierce has been compiling a mailing list, so far as he knows, of men who are interested, and I thought I would make the announcement to-day that, if any one would like a copy, if he will notify Mr. C. H. Pierce at the Custom House Building, Boston, he will be very glad to put his name on the list and send him a copy. The publication is No. 415 of the Water Supply papers of the Geological Survey. I don't know how large an edition is being issued, but I should recommend those who wish to get a copy to send reasonably early, because such editions are at times exhausted. It is certainly a very valuable publication, and a great deal of work has been put into it. Another year there will be a supplementary report issued covering similar ground, and if any superintendents or engineers have the flows of streams or water-works data which they could send him, it would be very acceptable in preparing a complete record of the flows of Massachusetts and the New England states.

President Sullivan. I wonder if "Eglee's" is out for this week? In these strenuous times he ought to have something to say.

Mr. Charles H. Eglee.* In these "strenuous times," as our President has termed them, you want some one to speak to you who will take the edge off of the strenuosity; and when you call on Eglee to speak, you want him to say something that will be light and cheerful and happy and foolish and frivolous. But I do not feel at all like speaking along those lines to-day.

Mr. President, I think in these "strenuous times" it is not wise to blunt our feelings to the momentous questions that are continually arising, and I believe that there has been something put before us, in the daily papers of yesterday and to-day, that every thoughtful man in this country ought to stop and consider. And if you will give me five minutes, we will think a little on this question of "peace." I don't know whether you want any such question intruded upon this meeting or not, but I have been thinking about it for several hours, and it seems to me I have a good chance to ventilate myself right now while you can't help yourselves.

We want peace. We want peace in our personal lives; we want peace in our business lives; we want peace in our national lives; and we want to see the warring nations stop this furious combat; but we don't want to see any sort of peace in our lives, in our business nor in the nations, unless that peace is a *right* peace. I am thoroughly in accord with the sentiment voiced by Mr. Beck two nights ago, at the Pennsylvania dinner, that there is something that is greater than peace, and that is honor, national honor; but we have seen all these nations abroad doing all the things that they possibly can do against their own national honor. I don't know where to put a finger on a lovely spot in this war. The efficiency of Germany, so great, has led her people into a condition where they are under a military domination that all of them cannot accept. Russia, with its beautiful simplicity of character, is under the selfish rule of a grafting nobility. England's aggressiveness and selfishness have carried her into all portions of the globe, and she can't help monkeying with our mails at the present time. I don't know that there is anything to be said about France, excepting in admiration of the virility and thrift of her people. These nations are all fighting furiously. They can't

* Hydraulic Engineer, Brookline, Mass.

get together, yet they say they want to have peace, and we in this country don't seem to want them to be at peace. Why, the "war brides" we have been flirting with are to-day indisposed, and the "babies" we have been bringing up are in convulsions.

We may talk about the peace of Europe, but does it not depend a very great deal upon this country? Because we see so many nations exhibiting their worst traits at the present time, it doesn't mean that they haven't good traits. That delightful simplicity of the Russian character that has been exploited so long; that wonderful thrift and virility of the French I have spoken of; that determined and dogged perseverance of the English people; that wonderful efficiency of the Germans, — how are all those excellent qualities to be brought together? How are they going to make a peace that will be lasting, not a truce that shall merely be a preparation for a war thirty or forty or may be ten years from now? They are going to do it through this country, because we have taken all these various qualities, welded them and amalgamated them and brought them into some sort of national spirit here. And yet we too are to-day exhibiting the worst side of our character through this ugly war, seeming to care only about how much money we are going to make out of it. This is a pity, because the time is coming when the national character of the American people must be used in helping to procure this honorable peace that shall last for the next thousand years.

And how are we going to do it? We are going to do it by an expression of the righteous opinion of the American people. It is up to you, and it is up to me, and it is up to the individuals of this community and of other communities of the states and of the nation, to think about these things and mark out a straight course, not by way of expediency but by the way of principle. We can never have peace in our lives unless we have determined upon a principle and have followed that principle. And it is up to us who have taken in and made use of all these various characteristics of all these various peoples, and have shown what we can do with them in the mass, to think through this question and to determine that principle of honorable peace that we at the proper time can lay before the other peoples for their consideration. It will not do that this country shall say, We are not concerned with

the causes of this war. There was a man once who was asked what became of his brother, and he said, "Am I my brother's keeper?" We have been in a mess about that ever since, and we will be in a mess to-day if we say that same thing again. We *are* concerned, and it is up to us, before we get through, to do the right thing and not the expedient thing. I will leave that thought in your minds, gentlemen.

The paper on the program for the afternoon was by Mr. Thorndike Saville, of Cambridge, Mass., and the subject was, "The Nature of Color in Water." It was discussed by Professor Whipple, Mr. Johnson, and Mr. Francis F. Longley.

Mr. Robert Spurr Weston, consulting engineer, Boston, Mass., gave an interesting illustrated talk on "Water Works in Cuba, and Other Things."

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, Mass., January 10, 1917.

The President, Mr. William F. Sullivan, in the chair.

The following members and guests were present:

Honorary Members.

Edwin C. Brooks.	Frank E. Hall.	Robert J. Thomas. — 4.
Albert S. Glover.		

Members.

R. C. Allen.	R. H. Ellis.	H. A. Hanscom.
L. M. Bancroft.	E. D. Eldredge.	L. M. Hastings.
F. A. Barbour.	G. H. Finneran.	T. G. Hazard, Jr.
A. E. Blackmer.	John Franklin.	D. A. Heffernan.
J. W. Blackmer.	F. L. Fuller.	C. R. Hildred.
George Cassell.	Patrick Gear.	J. L. Howard.
F. M. Cole.	H T. Gidley.	A. C. Howes.
A. W. Cuddeback.	F. J. Gifford.	E. F. Hughes.
John Cullen.	X. H. Goodnough.	G. A. Johnson.
C. E. Davis.	F. H. Gunther.	W. S. Johnson.
A. O. Doane.	R. A. Hale.	F. T. Kemble.
John Doyle.	R. K. Hale.	E. W. Kent.

Willard Kent.
S. E. Killam.
G. A. King.
John Knickerbacker.
G. H. Leland.
W. J. Lumbert.
P. J. Lucey.
Thomas McKenzie.
Hugh McLean.
A. E. Martin.
W. E. Maybury.
F. E. Merrill.
G. F. Merrill.
Leonard Metcalf.
Hiram A. Miller.
William Naylor.
T. A. Peirce.
H. E. Perry.
A. E. Pickup.
H. G. Pillsbury.
C. R. Preston.
Henry Richards.
L. C. Robinson.
B. F. Rogers.
A. T. Safford.
C. M. Saville.
Thorndike Saville.
J. E. Sheldon.
C. W. Sherman.
E. C. Sherman.
M. A. Sinclair.
J. Waldo Smith.
Sidney Smith.
G. H. Snell.
O. H. Starkweather.
W. M. Stone.
G. A. Stowers.
W. F. Sullivan.
H. A. Symonds.
E. A. Taylor.
Milton Thorne.
L. D. Thorpe.
J. L. Tighe.
E. J. Titcomb.
D. N. Tower.
C. H. Tuttle.
W. H. Vaughn.
J. H. Walsh.
R. S. Weston.
R. M. Whittet.
F. B. Wilkins.
H. F. P. Wilkins.
F. I. Winslow.
I. S. Wood.
Edward Wright.
M. B. Wright.
C. W. Young. — 93.

Associates.

Harold L. Bond Co., H. H. Sinclair, F. M. Bates.
Builders Iron Foundry Co., A. B. Coulters, G. H. Lewis.
Central Foundry Co., W. H. Felt, R. W. Conrow.
Eddy Valve Co., H. R. Prescott.
Fire and Water Engineering, Fred Shepperd.
F. H. Hayes Machinery Co., F. H. Hayes.
Hersey Mfg. Co., Albert S. Glover, W. A. Hersey, J. Herman Smith.
Lead Lined Iron Pipe Co., T. E. Dwyer.
Ludlow Valve Mfg. Co., A. R. Taylor.
H. Mueller Mfg. Co., G. A. Caldwell.
National Meter Co., J. G. Lufkin.
Neptune Meter Co., H. H. Kinsey, R. D. Wertz.
Pittsburgh Meter Co., J. W. Turner.
Rensselaer Valve Co., C. L. Brown.
Thomson Meter Co., E. M. Shedd, S. D. Higley.
Union Water Meter Co., D. K. Otis, F. E. Hall.
United States Cast Iron Pipe & Foundry Co., C. Donaldson.
Warren Foundry & Machine Co., J. H. Morrison.
Water Works Equipment Co., W. H. Van Winkle.
R. D. Wood & Co., H. M. Simons.
Henry R. Worthington, Samuel Harrison, W. F. Bird, E. P. Howard. — 31.

GUESTS.

NEW HAMPSHIRE.	MASSACHUSETTS.	RHODE ISLAND.
Nashua, Mayor James B. Crowley; John H. Stark, president Pennichuck Water Works.	*Holyoke,* Daniel Long, P. E. Pear.	*East Greenwich,* James Kinlock.
Concord, T. W. D. Worthen, Public Service Commission.	*Boston,* Martin R. Lane, W. O. Teague.	**NEW YORK.**
	Billerica, Frank L. Day.	*New York,* A. H. Howard. — 10.

The Secretary presented applications for active membership, properly endorsed and recommended by the Executive Committee, as follows:

William H. O'Brien, Chicopee, Mass., foreman Chicopee Water Department; John F. Sullivan, Chicopee, Mass., superintendent Chicopee Water Department; C. A. Stevens, Cummington, Mass., water commissioner; Dudley Chipley, Columbus, Ga., engineer and superintendent Columbus Water Works.

On motion, the Secretary was directed to cast the ballot of the Association in favor of the applicants named, and, he having done so, they were declared duly elected members of the Association.

PRESIDENT SULLIVAN. Mr. Edward C. Niles, chairman of the Public Service Commission of New Hampshire, is unable to be with us to-day, but happily we have an associate of his from the Commission. Within a few years many states in the Union have created public service commissions, and the men appointed on these commissions have been able, broad-gaged, fair, and judicial, and the public and the public service corporations were indeed fortunate in having the states make laws creating public service commissions. These public service commissions protect the public against grasping corporations, and they certainly act as a buffer between the public and the public service corporations. They are a protection to the public and they are a greater protection, I believe, to the public service corporations, because they deal out justice to them, and that is all they desire. Commissions have a difficult and intricate work before them, broadening all the time. When you think of the railroads, street railways, water, gas, electricity, and telephone problems which they have to solve and do the just and fair thing for everybody, for both sides, you can

imagine the job they have. It is a big job. It is a man's job. And we are fortunate to-day in having with us Prof. Thomas W. D. Worthen, member of the Public Service Commission of New Hampshire, who will talk to us on "Public Service Regulation and Control." I believe it is almost inevitable that regulation and control by commissions must broaden out from the public service corporations to the publicly operated utilities.

On motion of Mr. George Cassell, a rising vote of thanks was extended to the speaker.

Professor Worthen's paper was discussed by Mr. Leonard Metcalf.

The Association next listened to a paper entitled, "The First Slow Sand Filter in the State of Maine," by Henry Richards, trustee Gardiner Water District, Gardiner, Me., the paper being discussed by Mr. A. T. Safford.

The President read the report of the Executive Committee.

Report of the Executive Committee.

Boston, Mass., January 10, 1917.

Early in the year, a Membership Committee was appointed, with Mr. R. C. P. Coggeshall chairman, and Mr. W. S. Johnson secretary. Immediately this committee set to work to increase our membership, and it did effective work, Mr. Johnson devoting much time and thought in an effort to reach many who are eligible.

The membership to date is.	1 043
Initiated, reinstated, and qualified	150
Resigned and dropped	60
Died	8
Net gain in members	82

It is with regret we record the deaths of one honorary member and seven active members, as follows: E. D. Leavitt, George E. Crowell, J. W. Ellis, W. H. Jacques, G. L. Learned, T. H. McKenzie, D. A. Sutherland, and E. L. Peene.

The Boston meetings have been held regularly, as provided for by the constitution. These meetings have been a success socially and educationally. The June field day, like the one of the previous year, took the form of a joint outing with the Boston Society

Year.	President	Membership at End of Year.				Annual Convention.		Receipts for Year.	Expenditures for Year.	Total Balance at End of Year.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	*Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	*Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 271.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	*Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	692	Springfield, Mass.	Sept. 11–13, '07	5 291.83	4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	†2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	4 566.84	†3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	7 237.60	†2 719.05
1911	Allen Hazen	680	58	12	750	Gloucester, Mass.	Sept. 13–15, '11	6 440.90	6 279.72	†2 880.23
1912	Geo. W. Batchelder	666	53	12	731	Washington, D. C.	Sept. 18–20, '12	6 861.65	5 934.56	†3 807.32
1913	J. Waldo Smith	686	60	12	758	Philadelphia, Pa.	Sept. 10–12, '13	6 122.81	6 533.62	†3 396.51
1914	Frank A. McInnes	766	70	11	847	Boston, Mass.	Sept. 9–11, '14	7 686.17	7 437.17	†3 645.51
1915	Leonard Metcalf	862	81	18	961	New York, N. Y.	Sept. 7–9, '15	7 338.56	8 569.16	†2 414.91
1916	William F. Sullivan	942	84	17	1043	Portland, Me.	Sept. 13–15, '16	9 022.09	9 017.43	†2 419.57

*Deceased. †Does not include $1 815 invested in bonds.

of Civil Engineers. A delightful sail and dinner, with an entertainment, gave our members much enjoyment. The Boston Society of Civil Engineers on this occasion had as an honored guest Admiral Robert E. Peary, who talked to us in a most interesting and instructive way on "Preparedness." The day was featured by a "red-hot" ball game between the Society and the Association, and it was our pleasure to see the New England boys wallop the Engineers.

The Annual Convention at Portland, Me., was a great success in attendance and in interest. The business sessions were unusually well attended. Discussions were general, and provoked a lively interest. The topics discussed were timely and of great value to our members. The outings provided by the committee, headed by Mr. W. S. Johnson, were splendid affairs, a continuous round of festivity, run off on schedule time. These outings gave our members an opportunity to view the beautiful city and harbor and the excellent water supply of Portland. The hospitality of the "Forest City" was genuine and hearty.

The papers and talks this year have been of the usual high standard of excellence. They have been instructive and enjoyable.

A number of committees have been appointed on special subjects this year. The personnel of these committees promises much valuable information on questions and policies pertaining to our work.

The Committee on Meter Rates, Allen Hazen, chairman, has made its final report, which has been accepted. This report makes an important contribution to water-works literature.

The Committee on Standard Hydrant Specifications has not as yet made its final report.

The Committee on Brackett Memorial has completed the work assigned to it. This report and the recommendations it contained have been adopted by the Association. Great care in the future must be exercised in carrying out the provisions of this report.

The other special committees are devoting time and work to the matters in hand, and we are assured when we receive the reports and when these reports are spread on our records, the members of this Association will have material of great value.

This year the JOURNAL has maintained the high place it holds among publications of this kind. Early in the year our Editor, Major Richard K. Hale, responded to the call for troops on the Mexican border. Happily, he has now returned. During his absence the Board of Editors were fortunate in securing the services of Mr. Edward C. Sherman who, although suddenly called upon to assume the task, did it with zeal and carried the work along with efficiency and dispatch.

This year there was issued, at a net expense of $591.04, a complete index to our JOURNAL. This volume contains an author's index and a subject index. This index will be of great assistance to our members.

This year the Executive Committee voted jointly with the Boston Society of Civil Engineers to rent an additional room for headquarters purposes. The extra room will furnish the Association with much-needed facilities and will enable the Assistant Secretary to transact the rapidly growing business much more efficiently. A joint committee has agreed upon terms and furnishings.

Owing to the increased work performed by the Assistant Secretary, the Executive Committee voted unanimously to increase the salary of this position from six hundred to eight hundred dollars per year.

The financial statement of the Association is shown in the report of the Treasurer.

Your Executive Committee has considered the matter of increasing our income. A special committee, with our advertising agent, Mr. Geo. A. King, as chairman, is to make an effort to enlarge the scope of our JOURNAL as an advertising medium. We all feel that our JOURNAL offers exceptional opportunities to advertisers, and we would urge our members to assist this committee and to show to advertisers that the JOURNAL's index to advertisers is often referred to when buying materials and supplies. We need your support to convince non-advertisers that the JOURNAL is not only read and kept on file, but is considered of great value when one seeks the names and addresses of manufacturers. Will you coöperate with this committee so that the advertising columns of the JOURNAL may be made more useful to our members and more profitable to the advertisers?

The Secretary, Mr. Willard Kent, presented his annual report.

Report of the Secretary.

January 1, 1917.

Mr. President and Gentlemen of the New England Water Works Association,— The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 1 043, constituted as follows: 17 Honorary, 942 Members, and 84 Associates. That of one year ago was 961, comprised of 18 Honorary, 862 Members, and 81 Associates. A net gain for the year of 82. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1916.	Honorary Members	18			
	Died	1			
		—			17
January 1, 1916.	Total Members		862		
	Resigned	20			
	Dropped	30			
	Died	7			
		—	57		
			—	805	
	Initiations:				
	January	9			
	February	8			
	March	5			
	June	65			
	September	35			
	November	7			
	December	3			
		—		132	
	Reinstated:				
	Member resigned '04	1			
	Member resigned '16	1			
		—	2		
	Elected 1914, qualified 1916		2		
	Elected 1915, qualified 1916		1		
			—	5	
				—	942
January 1, 1916.	Total Associates		81		
	Resigned	7			
	Dropped	3			
		—	10		
			—	71	

	Initiations:			
	February	1		
	March	1		
	June	1		
	September	9		
		—	12	
	Reinstated:			
	Associate resigned, 1906		1	
			—	13
				— 84
January 1, 1917.	Total membership			1 043
January 1, 1916.	Total membership			961
	Net gain			82

The Secretary has received and paid to the Treasurer, $7 689.71. Of this amount the

Receipts for initiation fees were	$682.00		
From dues of members	2 471.00		
From dues of members, fractional	195.00		
From dues of members, past	4.00		
		$3 352.00	
From dues of Associates	$1 115.00		
From dues of Associates, fractional	78.75		
		1 193.75	
Total from dues			$4 545.75
From advertisements			1 765.00
From subscriptions			231.00
From JOURNALS			265.50
From sundries			882.46
Total as above			$7,689.71

There is due the Association at this date:

For advertising	$78.75
For specifications	10.00
For certificate	7.50
For subscription	18.00
For JOURNAL	4.00
Total amount due	$118.25

Respectfully submitted,

WILLARD KENT, *Secretary.*

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report:

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$140.57
Initiation fees	$682.00	
Dues	3 863.75	
Total received from members		4,545.75
JOURNAL:		
Advertisements	$1 765.00	
Subscriptions	231.00	
Sale of JOURNALS	265.50	
Sale of Reprints	26.15	
Total received from JOURNAL		2 287.65
Miscellaneous receipts:		
Sale of "Pipe Specifications"	$32.70	
Dinners	708.00	
Certificates of membership	81.00	
Buttons	6.00	
Index	4.00	
Dexter Brackett Memorial Committee	197.34	
Manufacturers Association	1 000.00	
Miscellaneous	19.08	
Total miscellaneous receipts		2 048.12
Total receipts		$9 022.09

Expenditures.

JOURNAL:		
Advertising Agent's commission	$239.00	
Plates	97.61	
Printing	2 066.99	
Editor's salary	225.00	
Expense	35.25	
Advance reports	131.46	
Reporting	242.20	
Reprints	225.15	
Envelopes and postage	78.48	
		$3 341.14

LEWIS M. BANCROFT, *Treasurer*,

In account with the New England Water Works Association.

RECEIPTS.

1916.			
Jan. 1.	Balance on hand		$2 414.91
	Received of Willard Kent, Secretary		7 689.71
	Interest on bonds and deposits		135.04
	Brackett Memorial Committee		197.34
	Manufacturers' Association		1 000.00
			$11 437.00

EXPENDITURES.

Bills paid		$8 017.43
Paid Treasurer Convention Committee		1 000.00
BALANCE ON HAND.		
People's Savings Bank	$2 000.00	
Mechanics Savings Bank	388.00	
First National Bank	20.33	
Liberty Trust Co.	11.24	
		2 419.57
		$11 437.00

ASSETS AND LIABILITIES.

ASSETS.

Cash balance in banks		$2 419.57
Bonds Nos. 2642 and 2644, Lake Shore & Mich. Southern R. R. 4%, due May 1, 1931. Book value, $1 815.00. Market value		1 920.00
Accounts receivable:		
JOURNALS	$4.00	
Advertising	78.75	
Subscriptions	18.00	
Certificates	7.50	
Specifications	10.00	
		118.25
		$4 457.82

LIABILITIES.

Accounts payable:	
Samuel Usher	$579.24
D. Gillies Sons	37.45
S. M. James	49.60
Surplus	3 791.53
	$4 457.82

READING, January 8, 1917.

LEWIS M. BANCROFT, *Treasurer*.

Office:			
Secretary, salary		$200.00	
Expense		27.40	
Assistant Secretary, salary		800.00	
Expense		372.12	
Rent		404.17	
Printing, stationery, and postage		279.68	
Membership lists		191.00	
			$2 274.37
Meetings and Committees:			
Stereopticon		$40.00	
Dinners	$744.20		
Cigars	51.00		
Music	121.00		
		916.20	
Printing, stationery, and postage		862.62	
Badges		108.57	
Banners		8.00	
June outing		3.48	
Traveling expenses		59.00	
Reporting		108.70	
			2 106.57
Treasurer's salary and bond			67.50
Certificates of membership			25.81
Pipe specifications			30.50
Index			151.00
Miscellaneous			20.54
Convention Committee			1 000.00
			$9 017.43

The Editor, Mr. Richard K. Hale, reported as follows:

Report of the Editor.

Boston, January 10, 1917.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1916.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of Volume 30 of the Journal, and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat larger than average.

Illustrations.—The total cost of illustrations for the year, including printing, has been $224.26, or 6.6 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge, and additional reprints, when desired, at the cost of the paper and press work. The net cost to the Association for reprints has been $174.25. There have been advance copies of ten papers prepared during the year, at a cost of $137.46.

Circulation. — The present circulation of the JOURNAL is:

Members, all grades	1 043
Subscribers	83
Exchanges	29
Total	1 155

an increase of 76 over the preceding year. JOURNALS have also been sent to 43 advertisers.

Advertisements. — There has been an average of 25 pages of paid advertising, with an income of $1 698, a slight decrease over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $32.70 have been sold; 500 were printed at a cost of $30.50. The net gain up to a year ago had been $294.25, so that the total net gain from this source to date is $296.45. There are still about 300 copies of specifications on hand, or about $30.00 worth if sold at retail.

The Association has a credit of $8.99 at the Boston Post-Office, being the balance of the money deposited for payment of postage upon the JOURNAL at pound rates.

Index. — An index of the JOURNAL and of Transactions, covering the years 1882 to 1915 inclusive, was published during the current year at a net cost of $591.04.

During the absence of the Editor from the state this summer, Mr. Edward C. Sherman took over the duties of that office.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE 1.

STATEMENT OF MATERIAL IN VOLUME XXX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1916.

Number.	Date.	Pages of Papers.	Pages of Proceedings.	Pages of Total Text.	Pages of Index.	Pages of Advertisements.	Pages of Cover and Contents.	Pages of Insert Plates.	Pages of Total.	Total Cuts.
1	March	142	40	182	..	32	4	9	227	26
2	June	106	12	118	..	32	4	4	158	16
3	September	111	1	112	..	32	4	2	150	13
4	December	66	60	126	8	32	4	2	172	2
	Total	425	113	538	8	128	16	17	707	57

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1916.

Receipts.

Advertisements	$1 692.50
Sale of JOURNALS	265.50
Sale of Reprints	25.65
Subscriptions	231.00
	$2 214.65
Net cost of JOURNAL	1 171.98
	$3 386.63

Expenditures.

Printing JOURNAL	$1 997.98
Printing illustrations	101.96
Preparing illustrations,	122.30
Editor's salary	300.00
Editor's incidentals	46.33
Advertising Agent's commission	238.50
Reporting	242.20
Reprints	199.90
Advance copies	137.46
	$3 386.63

TABLE 3.

Comparison between Volumes XXI to XXX, Inclusive, New England Water Works Association.

	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.	Vol. XXV. 1911.	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.
Average edition (copies printed)	1 085	1 000	1 000	1 150	1 000	1 000	1 000	1 050	1 325	1 500
Average membership	693	699	710	732	752	740	745	803	904	1 002
Circulation at end of year	785	780	802	827	840	826	858	951	1 079	1 155
Pages of text	500	500	459	643	475	401	554	564	596	538
Pages of text per 1 000 members	722	715	646	880	632	542	746	702	659	538
Total pages, all kinds	669	681	627	808	654	567	733	719	776	707
Total pages per 1 000 members	964	976	884	1 090	870	766	984	895	859	707
Gross Cost:										
Total	$2 643.42	$2 733.61	$3 111.15	$3 490.81	$2 625.87	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63
Per page	3.95	4.01	4.97	4.32	4.02	4.37	4.89	4.65	5.47	4.79
Per member	3.82	3.91	4.39	4.78	3.50	3.35	4.81	4.17	4.68	3.38
Per member per 1 000 pages	5.70	5.88	7.00	5.90	4.09	5.90	6.46	5.80	6.02	4.79
Per member per 1 000 pages text	7.62	8.02	9.56	7.44	7.36	8.35	8.68	7.39	7.85	6.30
Net Cost:										
Total	$483.15	$131.06	$789.98	$1 334.06	$352.82	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98
Per page	.72	.19	1.26	1.65	.54	.17	1.80	1.61	2.70	1.65
Per member	.70	.19	1.11	1.82	.47	.13	1.78	1.44	2.32	1.17
Per member per 1 000 pages	1.04	.28	1.78	2.25	.55	.23	2.42	2.00	2.98	1.65
Per member per 1 000 pages text	1.39	.39	2.43	2.83	.98	.33	2.38	2.55	3.88	2.17

The Auditing Committee submitted the following report:

Report of Auditing Committee.

Boston, Mass., January 8, 1917.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

Respectfully submitted,

GEO. H. FINNERAN,
D. N. TOWER,
Auditing Committee.

(On motion duly made, it was voted that the reports read be accepted and spread upon the records in the Journal.)

Mr. William F. Sullivan, the retiring President, then made his address.

Presidential Address.

Delivered before the New England Water Works Association, January 10, 1917, by William F. Sullivan.

The year 1916 has been a wonderful one for big business. Industries have been more prosperous than ever before in their history. Many concerns once struggling for existence have been obliged to run their plants to the limit. So the year just closed has been an extraordinary one for water-works managers.

Unusual and unnatural economic conditions have been brought about by the press of general business prosperity. Prices have increased in almost all directions. Needed supplies have soared in price to such heights as to have counseled prudence in the early months of the year. Some of us were convinced that it would be good policy as well as good business to mark time on large purchases and to delay construction. While discretion said " Wait," a portion of the public would not.

People with money or credit, spurred on by increased wages and flushed by what appears to be factitious prosperity, cast aside their usual thrift and ideas of economy and went ahead with new construction regardless of the cost. The result of this boom building has been the pyramiding of demands on labor and ma-

terials. I do not believe any one would say that this activity is not good for a community. But, to meet the requirements, utilities have been compelled to follow after this development and at times speculative craze. Naturally, the most needed conveniences to round out and complete this work are improved streets, sidewalks, water, sewers, and lighting, the most needful of these being water. Owners and promoters usually have been able to exert an influence to have the water supply extended to their premises regardless of current costs. It goes without saying that it is the duty and is usually the policy of all utilities to meet these obligations if reasonable. Water departments and water companies, however, cannot go on *ad infinitum* in the quest of new business without adequate compensation.

The returns to-day are based on previous costs of work and service, and are out of proportion to present-day costs and expenses. The tentative resolution which some of us took, early in the year, to mark time, was soon broken, and we have been in a way compelled to go ahead and lay pipes at a cost which thirty months ago we would have considered almost prohibitive.

Current prices are primarily due to the scarcity of labor, with the resultant increase in wages, and to the scarcity of raw materials. Minimum increase in cost of labor has been 25 per cent., cast-iron pipe 40 per cent., and in other supplies 30 per cent. Equipment and supplies which were formerly sold at discounts from time-honored lists are now in many cases plus such lists. Even with high prices the rule, it has been difficult to obtain the goods, and slow deliveries have become the custom.

Car shortage and embargoes on pipe and bulk freight have often delayed necessary work, especially work planned to be completed before weather conditions became too severe, such work having been started with the reasonable expectation of early deliveries. The result of this hold-up has been open trenches which have required lighting and care, frozen backfilling, increasing the cost. The railroads have been unyielding on their embargoes, which have seriously militated against the business interests of New England. Embargoes on shipments of cast-iron pipe have been in force over two months at a time. This delay, coming in the fag end of the year, has been a real hardship. Efforts for relief

have been futile, and thus we have been paying in money and inconvenience for conditions brought about by the European war.

Notwithstanding high costs, the nation's business has been prosperous, and most industries have been able to meet the changed conditions by automatically raising the prices of their products. By this means they have been able usually to lay aside large surpluses and often to distribute a part of the earnings to their employees in the form of bonuses or premiums, — all this in addition to substantial dividends to their stockholders.

On the other hand, how have the water-works finances fared under this unprecedented wave of prosperity? Occasionally we have received small increases in water revenue from speeded-up industries, which revenue seldom has offset the increased cost of service. The water-works business has been unable to meet the high costs because of its fixed rates which do not readily permit revision. The inflexibility of water rates renders us unable to adjust them to any rapid rise in the cost of our product.

With our inability to quickly readjust water rates under abnormal changes, what will be the remedy if costs are to continue as high as, if not higher than, at present? For water is still sold at the same old price, and in about the same quantities. The cost of water has not responded to the almost universal rise in prices. Water, that indispensable necessity, has not contributed to the high cost of living, for which a grateful public should be thankful.

To repeat, the water industry has been handicapped financially and otherwise by the inflated prices. If these new and abnormal conditions continue, or become in the future normal, then water works, whether public or private, must seek relief in increased rates if the public is to enjoy good service or if money is to be expended for new supplies, additions, and improvements.

Like nearly every one else, our Association has felt the effects of prevailing prices. Our dues and revenues have remained practically stationary, except for a considerable increase in income from entrance fees of new members. To offset this gain, printing, stationery, and sundries have kept step with high costs. If high prices are to be permanently established, this Association must consider ways and means of sound financing.

Speaking of our Association, what means this forced discussion

now going on? A well-known publication has taken upon itself the work of combining the two leading water-works associations of the country, with the belief that it would stop the loss of efficiency in them. The consequence of such combination would be the loss of this Association's identity and a prestige which has taken many years to build up. Evidently this magazine does not believe that "competition is the life of trade." Neither do I, when competition tends to hurt some one when that one is doing good. If there has been any competition between the American and the New England Water Works associations, it has always been friendly.

This publication says: "So long as old jealousies exist — and they will exist until the death of many of the older members — it is futile to talk consolidation." If that is a fact, why should this particular paper undertake at this time a campaign of consolidation? I firmly believe our old and active members have never been jealous of a sister organization. There is not now, and never has been, cause of envy. Many of our older members are or have been members of both organizations. Our members are not apprehensive of rivalship. Our members who belong to both, and those who have held office in both, have affection for both and are willing to sustain and defend both. Why this agitation for coalition? This year, like the preceding years, there has been neither discussion, agitation, nor any demand from within this Association for a merger or a subordination of its efforts or works to any other organization.

Why should this organization, at the height of its numerical strength and prosperity, wish to divide its success and its effective work? Why throw away our prestige and lose our unique position with the water-works interests of this continent? While it is true we may have a provincial name, our field of usefulness is as wide as the world.

Some of our members have been asked to express an opinion on the question of combination. Mark you, some of our members, not all. I do not know why not all. The replies from our active resident members have been timely, clear, and to the point. In substance, — no need to combine. I feel as if we should ignore this agitation. But I trust, as a loyal member, I have the right

to express my opinion that if a merger is necessary it will come about by proper and natural means and not through artificial channels.

The action of that magazine seems perilously near commercialism or exploitation. This campaign may have the effect of increasing circulation and furnishing advertisers with apparent proof of its influence. It looks like a hunt for new subscribers.

Did this publication know that its efforts were to create the impression that one organization was sufficient for the whole country or the world? And that it might have the effect that some members of both associations, believing that amalgamation was in sight, would fail to renew membership in one or the other? Or that prospective members of either Association might well wait and see what the outcome would be? Again, does this editor believe that manufacturers and supply men are unwilling to have "two shows"? Has it really come to this, — that American enterprise has relegated the motto "No trouble to show goods"? Or are the dealers so glutted with orders so far in advance that they do not want business? Do they think that the average water-works man should buy a "pig in a poke"? In the last analysis, who should determine, if not dominate, the sale, — the buyer or the seller? It might be well for all, if the supply men would state whether this magazine speaks authoritatively. While combination and merging may be the solution of many industrial problems, the uniting of human nature and the personal elements as found in social and technical organizations is something not easily accomplished.

Large and unwieldy organizations are a failure in centralizing thought and good-fellowship. The elimination of duplicate organizations is not practical. Imagine only one political party! Why not merge all the colleges and schools and have the students come to one center? Weak publications may combine, but would it be well to combine the strong leading magazines into a trust and get only trust thoughts and policies? It seems to me we want freedom of thought and ideas, the individual opinion of writers and thinkers, and not over-organized thought that is "shrimped and iced."

For many years the principal water-works associations have

been doing splendid work for the water-works fraternity, each in its own way and field, but often working together in the same vineyard. This work is not completed, and never will be. These strong, vigorous organizations should retain their entities. They are necessary for water-works interests and useful to their members.

The New England Water Works Association has always had its place in the light, and its loyal members trust it will always remain there. Our organization is managed entirely by its members. Our members largely know one another. We are unique in the spirit of friendship and fraternal kindness. The large and regular attendance at our meetings and conventions proves this. Our permanent and fixed headquarters are of great value. They are not subject to rotation from place to place on account of a change of officers.

There is much sentiment surrounding our Association, for it has been the alma mater for many a practical water-works man. Many of our more fortunate members have had the advantage of technical education, and they are among our most loyal and active members. They have benefited by the rich experience of many a man who has come up from the trench. Our practical and our technical men have always worked in unison, have given of their time, experience, and talents. This free exchange of information and knowledge has been one of the big assets of this Association. Practical members have received from the technical members knowledge of their calling that they could not easily obtain in any other way. Is it not true that parts of even the most abstract technical paper stay with the practical men? These papers give him a general insight into subjects that pertain to his line of work. They broaden his vision and enlarge his vocabulary.

The practical water-works man may not be able to analyze water, yet nowadays he is able to intelligently interpret a report. He may not be able to make a culture and count the bacteria, nevertheless he knows in a general way the mysteries of such. He may not be able to tell the difference between typhoid and colon bacilli, but he has seen both illustrated on the screen. So it is about color, iron, manganese, filters, pump tests, etc. He has received a liberal education from membership in this Association, by hearing or reading the high-grade, practical, technical, theoreti-

cal, and research papers which have been presented. The practical papers have been logical, sound, and helpful.

Along with the practical and educational advantages of our Association, we have the social side. All these and more we get as members. Would we not miss something in our little world if we could not come to these congenial meetings or attend the pomp of our conventions? Have we not a rich heritage from our eminent members who have gone? They left the strong impress of their personalities; our organization is richer, and we honor and cherish their memory. To-day we have as members solid, substantial builders, men who do things; also brilliant, able, and forceful minds, all contributing to one another's education. I am confident our members value highly membership in this Association. If it is to merge or be merged, let it not be by exploitation. The proposition should be carefully considered. Personally, I do not believe in combination because we have no prospect of anything in return. If the time ever comes, our members will approach the matter with an open mind. In the meantime let it be known near and far that the New England Water Works Association will continue to pursue the course marked out for it many years ago, that we shall strive to continue past successes and in the future work for greater activity, both educationally and socially.

Mr. John C. Chase. Mr. President, I want to express myself in a few words as heartily and thoroughly in favor of the law as you have just laid it down. I think you are deserving of a vote of thanks from this Association. I think also the part of your report that refers particularly to the publication ought to be sent to them, that they may use it in their editorial columns if they please.

I don't know why I should be singled out to be honored, as you may term it, with an invitation to express an opinion. I have a little curiosity to know if the opinion I expressed to them was in print. I seriously have my doubts about it, because I expressed myself in no uncertain way, practically on the lines you have indicated, and furthermore, to the extent that if any merger was to take place it would be a merger into the New England Association.

Gentlemen, I want to move to you that a vote of thanks be given to the President of this Association for his presentation of this case.

There seems to be no Vice-President present. I will ask all those in favor of the motion to manifest it by rising.

(The motion was adopted by the Association.)

Election of Officers,

The tellers appointed to canvass ballots for officers for the coming year submitted the following report:

Whole number of ballots	377
Blanks, 1; unsigned	2

President.

Caleb M. Saville	355
Scattering	1

Vice-Presidents.

Carleton E. Davis	360
Samuel E. Killam	365
Henry V. Macksey	361
Frank A. Barbour	361
Percy R. Sanders	359
Thomas McKenzie	361
Scattering	2

Secretary.

Willard Kent	360

Treasurer.

Lewis M. Bancroft	364

Editor.

Richard K. Hale	364

Advertising Agent.

George A. King	366

Additional Members Executive Committee.

William F. Sullivan	361
Frank J. Gifford	362
A. R. Hathaway	359
Scattering	1

Finance Committee.

Edward D. Eldredge	362
A. E. Pickup	362
Bertram Brewer	363

Respectfully submitted,

DAVID A. HEFFERNAN,
WM. J. LUMBERT,
FREDERIC I. WINSLOW,
Tellers.

The President. You have heard the report of the committee appointed. These gentlemen named are the respective officers for the ensuing year.

In retiring from the office of President, I wish to thank all the members of the committees and officers for the faithful support they have given me. No one ever received more prompt support and assistance. I never called upon any one for assistance without immediate response. The best I ask for the incoming administration is that you show to them the same kindliness, loyalty, and friendship that you have shown to this administration. If you do, the incoming administration will go on and show greater success than we have shown this year. True, we have lifted the membership over 1,000, and I trust you will lift the membership over 1 100 this year. It is a big task you have got, Mr. Incoming President.

The incoming President is a man who has always taken a keen interest in the Association. He has contributed papers of great value. You all know him. And it gives me great pleasure to present to you the incoming President of the New England Water Works Association, Mr. Caleb Mills Saville.

Mr. Saville, the incoming President, then addressed the Association as follows:

Incoming President's Address.

Mr. President and Gentlemen, — In looking back over the long roll of efficient water-works men who have received from your hands the honor of being made President of the New England Water Works Association, it has been impressed upon me that

the duties of this position are not to be lightly undertaken if the high standard which has been set is to be maintained.

To follow in the footsteps of such men as Brackett, FitzGerald, Sedgwick, and others, makes this a distinction to be highly prized by water-works men.

No laurels, however, are worth while which can be had without effort, and as you have seen fit to honor me with this office, which I assure you I greatly appreciate, I undertake to do all that in me lies to forward the best interests of the New England Water Works Association.

Individual effort, rightly placed, will accomplish much, but constant coöperation of many minds and hands is irresistible. This is our association, — yours and mine; you too, have a duty to perform, and one which as managers, superintendents, and engineers you owe not only to the water-works fraternity but to the public at large.

Into your hands is committed the most important of all public responsibilities, — the safeguarding of the nation's health. To do this honestly, efficiently, and economically is a man's work.

The precedents of this Association are replete with examples of the highest type of character as well as of efficiency and progress in water-works affairs.

On you rests the burden of maintaining the high standard of manhood that is our inheritance.

To be of the utmost value to us, individually, and to the community at large, we must remain true to our traditions and devote our energies to the water-works problems of the day. We are not selling goods for a material house; we are selling our knowledge of water-works matters to the public. If we would succeed in our own work we must not be swerved aside from our purpose either by Circean blandishments similar to those of the old-time commercial drummer or the Machiavellian machinations of the wily politician.

This society is called the New England Water Works Association, and the bulk of its members are dwellers in the northeastern section of this country. Its early formation was sectional, and its original purpose was only to enable local water-works men in New England to get together and talk, heart to heart, about the

special matters that perplexed them. The fame of its good work and high ideals spread, and other serious-minded men with like problems recognized its value and desired to be enrolled among its members, until now its membership is limited only by the confines of the world.

Its papers, its morale, its purpose, the conduct of its members and their meetings, have been such that earnest and thinking men are proud of their connection with this Association.

Its aim and object is to discuss and meet work conditions confronting water-works men and especially those problems which are of local significance. To do this effectively we can allow this Association neither to degenerate into a social club nor to entertain ambitions for power in national affairs.

"By their deeds shall ye know them," and by the conduct of our meetings will our Association gain or lose in public opinion. It is no more simple matter to serve two masters under work-a-day conditions than it is under the moral law. It is impossible to hold frivolous meetings and expect the public to believe we are a serious body, earnestly working for its welfare.

We must recognize that great good is being done by others working in the same field as ourselves, and it should be our desire to coöperate and extend to them and to the nation our help in every possible way. We must, however, bear carefully in mind the Washington advice, "to avoid entangling alliances."

We should cling to the precepts and examples of the fathers of this Association, and to the fundamental principles that have placed and held it in its present enviable position.

Our past record is secure, and plainly shows that we have found our "place in the sun." It must be our constant endeavor to hold it against every onslaught, no matter how insidious.

Up to the present we have held this place honorably, "with charity to all and with malice toward none." With your help, mine is the privilege and duty to retain this high estate and keep the faith with the founders and builders of this Association.

Gentlemen, I have great pleasure in wishing you all a happy and prosperous coming year.

On motion duly made, the Association voted to adjourn.

February Meeting.

Hotel Brunswick,
Boston, February 14, 1917.

Caleb M. Saville, President, in the chair.
The following members and guests were present:

Honorary Members.

R. C. P. Coggeshall.
A. S. Glover.
F. E. Hall.
F. P. Stearns.
R. J. Thomas. — 5.

Members.

E. R. B. Allardice.
L. M. Bancroft.
H. K. Barrows.
G. W. Batchelder.
A. E. Blackmer.
J. W. Blackmer.
George Bowers.
Bertram Brewer.
James Burnie.
Eugene Carpenter.
George Cassell.
C. E. Chandler.
John C. Chase.
F. L. Cole.
F. W. Dean.
H. P. Eddy.
C. H. Eglee.
E. D. Eldredge.
R. H. Ellis.
F. F. Forbes.
Patrick Gear.
H. T. Gidley.
F. J. Gifford.
H. J. Goodale.
X. H. Goodnough.
P. T. Gray.
R. A. Hale.
R. K. Hale.
D. A. Hartwell.
A. R. Hathaway.
D. A. Heffernan.
A. C. Howes.
W. F. Howland.
A. W. Jepson.
W. S. Johnson.
Willard Kent.
G. A. King.
John Knickerbacker.
P. J. Lucey.
S. H. McKenzie.
Thomas McKenzie.
Hugh McLean.
H. V. Macksey.
E. H. Magoon.
A. E. Martin.
W. E. Maybury.
John Mayo.
F. E. Merrill.
G. F. Merrill.
H. A. Miller.
W. H. O'Brien.
J. W. O'Neill.
T. A. Peirce.
A. E. Pickup.
C. R. Preston.
L. C. Robinson.
G. A. Sampson.
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
G. H. Snell.
O. H. Starkweather.
J. F. Sullivan.
W. F. Sullivan.
C. N. Taylor.
Edwin A. Taylor.
L. D. Thorpe.
J. L. Tighe.
A. H. Tillson.
E. J. Titcomb.
D. N. Tower.
C. H. Tuttle.
C. L. Ward.
Percy Warren.
R. S. Weston.
F. E. Winsor.
I. S. Wood. — 77.

Associates.

Allen & Reed, Inc., Z. M. Jenks.
Harold L. Bond Co., F. M. Bates.
Builders Iron Foundry, A. B. Coulters, F. N. Connet.
A. M. Byers Co., H. F. Fiske.
Chapman Valve Mfg. Co., V. N. Bengle, James Mulgrew.
Eddy Valve Co., H. R. Prescott.
Fire and Water Engineering, Fred Shepperd.
F. H. Hayes Machinery Co., F. H. Hayes.
Hersey Mfg. Co., J. H. Smith.
Ludlow Valve Mfg. Co., A. R. Taylor.
H. Mueller Mfg. Co., G. A. Caldwell.
National Meter Co., H. L. Weston, J. G. Lufkin.
Neptune Meter Co., H. H. Kinsey, R. D. Wertz.
Pittsburgh Meter Co., J. W. Turner.
Rensselaer Valve Co., C. L. Brown.
A. P. Smith Mfg. Co., F. L. Northrop.
Standard Cast Iron Pipe and Foundry Co., W. F. Woodburn.
Thomson Meter Co., E. M. Shedd.
Union Water Meter Co., D. K. Otis.
R. D. Wood & Co., H. M. Simons.
Henry R. Worthington, W. F. Bird, Samuel Harrison. — 26.

Guests.

Maine.

Auburn, A. W. P. Cobb.

Massachusetts.

Brookline, D. Lacy, forester.
Chicopee, J. J. Page, Edward L. Frazier, water commissioners.
Cohasset, Dr. O. H. Howe.
Holyoke, C. C. Coyne.
Monument Beach, Theodore Chaffin, superintendent water works.
Somerville, William Myers.

Rhode Island.

Providence, M. H. Bronsdon, city engineer; John Kelso, commissioner.

Connecticut.

Bristol, C. L. Wooding, commissioner.
Norwich, C. B. Palmer, civil engineer.
New Haven, Prof. J. W. Toumey, director School of Forestry, Yale College.

Pennsylvania.

Philadelphia, F. A. Frank. — 14.

Applications for membership, properly endorsed and recommended by the Executive Committee, were presented by the Secretary as follows:

Resident — E. C. Wardwell, Waterville, Me., trustee Kennebec Water District; W. R. Ellis, Danielson, Conn., superintendent of local water works; Frederick A. Cole, Newtonville, Mass., engineer of water-works construction.

Non-Resident — Charles L. McNeil, Torrington, Conn., secretary and treasurer Torrington Water Company; John C. Ford,

Woodbury, N. J., superintendent Water Works; George F. Drew, Brunswick, Me., mill engineering.

On motion of Mr. Lewis M. Bancroft, the Secretary was instructed to cast one ballot in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

Mr. Frank Winsor, chief engineer Water Supply Board, city of Providence, R. I., gave an illustrated talk on the new water supply for that city. Mr. Frederic P. Stearns, consulting engineer; John Kelso, member of the Providence Water Board; Milton H. Bronsdon, city engineer, and Irving S. Wood, assistant city engineer in charge of the Water Department, Providence, also spoke.

Prof. J. W. Toumey, director School of Forestry, Yale College, New Haven, Conn., gave an address on "Forestry in Relation to Public Water Supplies." The subject was discussed by Mr. John Kelso, Providence Water Supply Board; Hiram A. Miller and Elliot R. B. Allardice, who spoke of the forestry work in connection with the Metropolitan Water Supply; William F. Sullivan, engineer and superintendent, Nashua, N. H.; Patrick Gear, superintendent, Holyoke; and Frank Winsor, chief engineer Water Supply Board, Providence, R. I.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association, December 13, 1916, at headquarters, Tremont Temple, at 11 A.M.

Present: President William F. Sullivan, and members Caleb M. Saville, Samuel E. Killam, D. A. Heffernan, R. C. P. Coggeshall, F. J. Gifford, Willard Kent, Richard K. Hale, Lewis M. Bancroft, and George A. King.

Five applications for membership were received, viz., Charles L. Crosier, assistant in civil engineering at Mass. Inst. of Technology, 316 Huntington Avenue, Boston, Mass.; Richard H. Ellis, superintendent Board of Public Works, North Andover, Mass.; James Menzies, superintendent Water Works, 387 George Street, Sydney, N. S.; Ernest H. Rigg, chairman of Water Committee, City Council, 132 Horace Street, Woodbury, N. J.; Thorndike Saville, assistant in municipal administration, Harvard University, 5 Sumner Road, Cambridge, Mass., and the several applicants were unanimously recommended therefor.

Chairman King, of the subcommittee on increase of revenue, reports suggesting that this committee advise that the attention of the incoming Executive Committee be called to the need of increasing the advertisements in the JOURNAL, and that the individual members of the committee may help this by personal solicitation; for the purpose of increasing the value of the advertisements to our patrons, that personal items and news items be incorporated among the advertisements; that there be an additional day given for the Annual Convention, this day to be for the use of the exhibitors, the day not to be either the first or the last day of the Convention.

Mr. George A. King, Mr. Caleb M. Saville, and Mr. Carleton E. Davis were made a committee to consider amendment to Constitution with reference to membership dues.

On motion of the Advertising Agent, Mr. George A. King, the

President was authorized to appoint a committee to consider the question of Advertising Agent's compensation. Messrs. Caleb M. Saville, Richard K. Hale, Samuel E. Killam, Lewis M. Bancroft, and Frank J. Gifford were made that committee.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, January 10, 1917.

Present: President William F. Sullivan, and members Caleb M. Saville, Carleton E. Davis, Samuel E. Killam, D. A. Heffernan, Robert J. Thomas, F. J. Gifford, Richard K. Hale, Lewis M. Bancroft, George A. King, and Willard Kent.

The following applications for membership were received and recommended therefor: Dudley Chipley, engineer and superintendent Water Works, Columbus, Ga.; William H. O'Brien, foreman Chicopee Water Department, 193 Hampden Street, Chicopee, Mass.; C. Ashley Stevens, water commissioner, Cummington, Mass.; John F. Sullivan, superintendent Chicopee Water Department, 109 Church Street, Chicopee Falls, Mass.

Messrs. Frederic P. Stearns, M. N. Baker, and A. E. Martin were by unanimous vote constituted a committee to recommend the award of the Dexter Brackett Memorial Medal for the year 1916.

Mr. W. S. Johnson, chairman of the Committee of Arrangements for the Annual Convention of 1916, presented the report of that committee, which was accepted and the recommendation that the Annual Convention of the Association in future be of four days' duration instead of three and that the Treasurer of the Association be *ex officio* a member of, and treasurer for, all committees of the Association controlling the expenditure of money, was by unanimous vote endorsed by the Executive Committee.

Voted: That the subject of the Water Works Manufacturers' Association's contribution to the expenses of the Annual Convention be referred to the Executive Committee of 1917.

President Sullivan presented a report for the Executive Committee, and by unanimous vote it was adopted as the report of the committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association, January 29, 1917, at headquarters, Tremont Temple, pursuant to call of the President.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, Frank J. Gifford, Willard Kent, Richard K. Hale, Lewis M. Bancroft, and George A. King.

The resignation of Mr. E. C. Sherman from the Committee on Furniture, on account of absence, was received and his duties on that committee were delegated to Mr. Killam.

The continuation certificate of the Treasurer's bond for five thousand dollars in the Massachusetts Bonding and Insurance Company, of Boston, Mass., from January 12, 1917, to January 12, 1918, was presented and by unanimous vote approved.

The resignation of Mr. Frederic P. Stearns from the Committee of Award of the Dexter Brackett Memorial Medal for 1916 was received, and on motion of Mr. Macksey, seconded by Mr. Bancroft, was accepted, and Mr. Desmond FitzGerald was elected to fill the vacancy on that committee.

After a general discussion of arrangements for the Annual Convention, the meeting was adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Wednesday, February 14, 1917, at 11.00 A.M.

Present: President Caleb M. Saville, Henry V. Macksey, Thomas McKenzie, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Richard K. Hale, Lewis M. Bancroft, George A. King, and Willard Kent.

Six applications were recommended, and the several applicants were by unanimous vote recommended for membership in the Association, viz.: Frederick A. Cole, engineer of water-works construction, Newtonville, Mass.; George F. Drew, resident engineer, Brunswick, Me.; W. R. Ellis, superintendent of local water works, Danielson, Conn.; John C. Ford, superintendent Water Department, Woodbury, N. J.; Charles L. McNeil, secretary and treasurer Torrington Water Co., Torrington, Conn.; and E. C. Wardwell, trustee Kennebec Water District, Waterville, Me.

Messrs. Hugh McLean, J. E. Sheldon, Charles C. Coyne, secretary Chamber of Commerce, of Holyoke, and A. S. Glover, W. S. Johnson, and R. C. P. Coggeshall were present by invitation, and matters pertaining to the annual convention were discussed.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

New England Water Works Association.

ORGANIZED 1882.

Vol. XXXI. June, 1917. No. 2.

PUBLIC-SERVICE REGULATION.

BY THOMAS W. D. WORTHEN, COMMISSIONER, NEW HAMPSHIRE PUBLIC SERVICE COMMISSION.

[*Read January 10, 1917.*]

From early times, common carriers and industries classed as public utilities have nominally been subject to regulation by common law, but the remedy has been ineffective on account of the expense and delay involved in bringing suits and getting decisions. The conduct of some of our railroads and other public-service corporations in excessive issues of stock, discriminations, inadequacy of service, etc., finally incited the public to demand that a tribunal more available than the court for securing fair relations between the public and these corporations be established. This resulted in a widespread determination to make the so-called public-service corporations the actual servants of the people by the enactment and enforcement of laws regulating the conditions of operation, the service rendered, and the charges to be made therefor. In some localities, a spirit of antagonism was aroused so that the corporations welcomed the establishment of a tribunal of ready reference for the settlement of differences connected with public service.

It was not until 1906 that large authority was given to the Interstate Commerce Commission. In 1907, Wisconsin and New York included the utilities in their field of regulation and appointed very efficient boards of commissioners. Massachusetts had already taken a step in advance in the appointment of a gas com-

mission in 1886. The work of these commissions has been epoch-making, and since 1907 the regulation and control of public-service corporations* has been entrusted to commissioners in forty-six states of the Union, — all except Delaware and Utah. The spirit of antagonism and retaliation which was manifested in some cases is no longer in evidence to any considerable extent, and in general a spirit of fairness prevails in the general public, the commissions, and the corporations.

It is pretty generally agreed that there can never be a return to competition to regulate prices in the public-service field. The experiment of public regulation is now being tried almost universally in this country, and, if it proves satisfactory to the masses, it will be permanent, and all depends on whether the masses take sufficient interest to make sure that suitable men compose the commissions. If regulation fails, public ownership is inevitable; and, for this, very high standards in theory and practice of the duties of citizenship are required. Regulation of public-service corporations should secure and maintain fair and just relations between those rendering the service and those served. This means for the public as good service as can reasonably be furnished at as low a price as is fair to the producer, and free from undue discrimination.

The industries or corporations classified as public-service corporations are usually arranged in two groups: First, railroads, which include steam and electric railroads and car and express companies. Second, utilities, which include gas, electric, telegraph, telephone, and water companies, and, in some states, toll bridges, ferry and other boats used in public transportation of passengers or freight, warehouses, etc. This classification applies to individuals and partnerships as well as corporations. The regulating boards in the various states are designated as railroad commissions, corporation commissions, public utility commissions, or public service commissions. The number of members is usually three or five. They are appointed in twenty-five states and elected in twenty-one states. The terms of office range from

* A single public-service plant of each variety is ordinarily adequate to serve a community, and a duplication involving unnecessary investment must inevitably require a larger revenue to carry on the business.

two to seven years. The salaries range from $1 500 to $15 000 per year. The number of subordinate employees ranges from one to six hundred. Every up-to-date public-service act authorizes the commissions to confer in person, by attending conventions, or otherwise, with the members of the commissions of other states and with the Interstate Commerce Commission, on any matters relating to public utilities.

As a full understanding of all the conditions involved is necessary in order to insure justice in any case, a commission Act contains a section to the following effect:

> "The commission or any commissioner or any person or persons employed by the commission shall upon demand have the right to inspect or examine the books, papers, accounts, documents, plant, property, and facilities of any public utility and to examine under oath any officer, agent, or employee of said public utility in relation to its business and affairs."

In this as in general, much depends on the spirit and manner in which the work is carried out. When it is recognized that it is done in the best interests of all parties, no friction is occasioned.

Accounts and Reports.

One of the first undertakings of every commission is to secure from each utility as full a report as possible of the character and extent of the plant or investment, and the character and extent of the operations. In this, as in all other lines of public-utility regulation work, the Wisconsin and New York commissions have done pioneer and extensive work. It is necessary in the first instance to send out comparatively simple forms to the various utilities, indicating the exact information desired. Our experience in this connection may be of interest. We sent out such forms and were greatly surprised at the lack of accounts to show cost of operation, plant investment, etc. It required a large part of the time of a clerk for a full year to get the reports in, and into such form as to make possible any comparison whatever of the operations of utilities of the same class. A great amount of work was done by correspondence, and a considerable number came to Concord to be personally conducted in making up their reports. The reports of the utilities for the second year were less than fifty per cent.

ready for printing when filed, and it was evident that a uniform system of accounts and records must be adopted. Comparative statistics of what has been done by the various utilities are essential for progress in efficiency. Ours is a *public*-service commission. Whenever it takes up a question of public interest it invites all who are involved or interested to meet in a public conference, so as to be sure to get all points of view. After securing legislative authority, we set about the considerable task of setting up a standard system of accounting adjusted to various conditions of the different utilities. It was done in this way: A tentative scheme was set up and distributed to the utilities. Electric utilities were taken up first. Criticisms and suggestions were requested. Three public meetings were held for discussion. The National Electric Light Association was represented, and careful comparison was made with the accounting system then under preparation by a committee of that association and already in use by several electric companies, so as to avoid minor differences not essential to the securing of the information deemed necessary for our record. Comparable schemes for four grades, A, B, C, and D, were adopted, and finally there was general agreement that the records were such as ought to be kept for the benefit of the companies themselves. Gas and water utilities were treated in like manner. Steam and electric railroads, express, telephone, and telegraph companies are in charge of the Interstate Commerce Commission, and blank forms with instructions are available for state use with modifications for local needs. In this way there is made available in convenient form the information necessary for a comparative study of like companies, which by making evident any lack of efficiency will be an aid toward uniform excellence in operation. I am sure that municipalities operating utilities will find these systems of accounting very helpful, and it would be very useful to the commissions to have records of the operation of utilities by municipalities available.

Adequacy and Safety of Service.

In general, the public-service law requires that the service and facilities of every public-service corporation shall be reasonably adequate and safe, and every service rule and practice shall be

just and reasonable, and it is made unlawful for any public-service corporation to make or permit to exist any unjust discrimination or undue preference with respect to its service or facilities.

The first requisite for any effective regulation under this article is to establish adequate standards of quality of service rendered or to be rendered by each class of public utilities, and to prescribe regulations for the examination and testing of the service and provide for the inspection of the manner in which each utility conforms to the regulations prescribed by the commission for the examination and testing of its service, and for the measurement thereof. Provision is made for the calibration, checking, or standardization, to secure the accuracy of measuring instruments used by any public utility, and in so doing the plan is to conform as closely as possible to the standards and methods of standardization of the National Bureau of Standards at Washington. I will give our experience in this connection.

Our first service complaint was in regard to gas, " quality poor," " price high." It was so, and it was remedied without formal hearing and with very substantial saving to the community.

After securing full legislative authority, gas utilities were first considered by the commission. The gas then being produced by the different companies was tested for heating value, pressure, and impurities, to determine the conditions then existing. A tentative set of rules was prepared and a conference held at which the various gas companies and the Bureau of Standards of Washington were represented. A set of rules was adopted which was considered reasonably fair, both to producers and consumers. The rules adopted prescribe standards of purity, pressure, and heating value of gas, and provide for periodic testing thereof, and for the testing of meters and for regulating the service of gas utilities in other ways.

Standards of service have also been established for electric, water, and telephone companies, and general improvement in service is expected. Much of the poor service was due to the fact that many utilities had no way of testing the quality of their service. Some consideration may be necessary while the regulations are being put into operation, but it devolves upon the utility to show the commission that a modification of some rule

or rules should be made in fairness to the utility. I am sure that these standards of service would be helpful to municipally operated utilities.

Rates.

The first general communication from our commission to the utilities was a request that all schedules of rates and all rates and contracts not scheduled be filed with the commission within a reasonable time. One utility reported, " We have no schedules, we take whatever anybody is willing to give us " ; but in explanation he said, " Our policy is to take all the business we can get and get as much as we can out of it."

Formal complaint was made to the commission that an electric utility did not make out its bills according to the rate schedule. The investigation disclosed that the utility used no fixed schedule. The method was to decide how much money was wanted and make out the bills accordingly.

Frequently a utility was saddled with rates made for the purpose of securing customers or favorable influence, or under pressure of various kinds, and it was not able to revise the schedule and make rates equitable without serious friction. Much of the work of adjustment is done by correspondence or conference, but occasionally cases require formal proceedings, investigations, and orders. Extreme cases are likely to be brought to the notice of the commission by petition or to attract attention in the consideration of capitalization or transfer cases, or in the comparison of the operation of utilities of the same class. Changes in schedules are very likely to be objected to, particularly if any rates are raised, which is usually the case when some customers have been enjoying specially low rates. Hence, utilities hesitate to change their schedules, although they are well aware that they are not just and equitable, and prefer to await the order of the commission. On the other hand, it is not a very uncommon thing for a company to carry out some scheme on its own motion and give as a reason that it is required to do so by the Public Service Commission.

All schedules of rates must be filed with the commission and posted in the main office of the utility or railroad, and all changes must be treated as schedules before they are made effective.

Rate Theory.

(A large part of what follows on rate theory and practice was prepared as a report to the National Association of Railway Commissioners.)

The usual statutory requirement is that all utility rates shall be just and reasonable. Just and reasonable rates are described to be such rates as produce a fair return on the fair value of the property in use and useful in carrying on the business, and, further, such rates as are free from preferences or undue discriminations between persons, localities, commodities, or classes of service. The same principles underlie utility and railroad rates, and these are clearly set forth in Smyth *v.* Ames (169 U. S. 546, 547):

> " The utmost that any corporation operating a public highway can rightfully demand . . . is that it receive what under all the circumstances is such compensation for the use of its property as will be just and reasonable both to it and to the public.
>
> " The basis of all calculations as to the reasonableness of rates . . . must be the fair value of the property being used by it for the convenience of the public.
>
> " What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public highway than the services rendered by it are reasonably worth."

Hence, at the outset of any rate study or investigation, it is necessary to determine the fair value and the fair rate of return as applied to the particular case under consideration.

Fair Value.

Volumes have been written on this subject, and as yet no fixed and definite principles have been generally accepted which reduce the work to the realms of arithmetic or even mathematics in general. Some one has said that the real problem, mathematically speaking, is to reduce the percentage of guesswork to a minimum. In many cases that is true. When the plant is of recent origin, or the books have been carefully kept from the beginning, so that the original cost can be ascertained and the amounts expended in extensions can be distinguished from the ordinary re-

pairs, which should be taken care of as part of the operating expenses, the actual cost to date can readily be found, and this is generally regarded as very important information provided there is reason to believe that it was wisely conceived, and that construction was properly made. Some regard this as the only thing to be considered when it is available. In most cases, however, the early books have been lost or they have not been so kept as to show the actual cost to date. The cost of an identical plant at date, or the cost of reproduction new, with allowance for depreciation, is regarded as an important factor, especially when actual cost cannot be discovered. The proper presentation of a modern scheme of cost of reproduction new would require much more time than we had at our disposal at the start. Some claim that property devoted to the public service is like any other property in this, that it is worth all it will sell for. Some would consider the capitalization, some the tax valuation, as having weight in determining fair value.

It has been well said that " the valuation of public utility undertakings is a mixed question of fact, judgment, and law." It has also been well said that " fair value must always be determined by the well-instructed judgment of a broad-minded and impartial tribunal." In this connection, reference is made to an excellent paper on " Rates for Water Supply,"* by B. M. Wagner.

Fair Return.

The amount of return should be such as to provide for the cost of economical and efficient operation, taxes, and depreciation, a fair net return on the fair value of the property devoted to public use, and a proper margin for the successful conduct of the business. Exceptional efficiency of management should receive consideration and encouragement.

Cost of Operation.

Cost of operation requires careful attention in rate questions; and in establishing a rate system, competent engineers and accountants must make such investigations as to determine ac-

* Journal N. E. W. W. A., XXIX, 1.

curately the degree of economy and efficiency with which the business is conducted.

Taxes.

The matter of taxes requires only to be noted, but attention is called to the fact that there is often an unjustifiable difference between the valuation on which taxes are paid and that on which rate of return is allowed. Ordinarily, these should be identical except in the case of property not useful to the service.

Depreciation.

The fair amount to be set aside for depreciation varies with local conditions, and can be determined only by a careful accounting for a long term of years. The extent to which replacements are included in operating expenses, and the thoroughness of the repairs and upkeep of the plant, have an important bearing on the additional amount necessary to be set aside to safeguard the investment.

The composite life of the plant, determined from the probable length of life of its various parts, gives a percentage which is taken as a working basis, and should be subject to such modifications as experience requires.

Example: If the composite life is found to be thirty-three and one-third years, giving a depreciation rate of three per cent. on a straight line basis, and replacements to the amount of two per cent. are included in operating expenses, only one per cent. additional would be assigned to depreciation.

Rates for depreciation allowed by commissions generally range from one per cent. to six per cent., according to conditions.

Rate of Net Return.

Fair rate of net return varies widely with local conditions. In general, the legal rate of interest may properly be taken as a standard of measure of the fair rate of net return to be distributed to the stockholders, but this may require modifications to fit cases which are exceptional in the amount of risk connected with the investment. When a business is of a permanent and stable character, and is free from irresponsible and destructive competi-

tion, the rate of net return may well approach that on bond and savings bank investments; and, on the other hand, when an exceptional element of risk pertains to the business, as in obsolescence of plant or obvious possibility of competition of other substitute service, a rate substantially above the legal rate of interest may fairly be allowed. (The legal rate of interest is five per cent. in three states, six per cent. in thirty-one states, seven per cent. in eight states, and eight per cent. in six states.)

Rates of net return allowed by commissions range in general from five per cent. to eight per cent., but, in municipal plants, rates ranging down to four per cent. have not been declared confiscatory, and as high as ten per cent. rates have been allowed in a few instances. There is a considerable twilight zone between a rate of return that would be declared confiscatory and the minimum rate of return that would be regarded as reasonable.

It must be borne in mind that there is no necessary relation between the stock and bonds outstanding and the fair value of the property. When the amount of stock equals that of the bonds, and they together equal the fair value of the investment, — a desirable but rare state of affairs, — the lower rate on the bonds allows a higher rate on the stock; e. g., if in such a case a six per cent. net rate of return is allowed on the fair value of the investment, a bond rate of four and one-half per cent. would allow a seven and one-half per cent. rate on the stock. The rate of net return allowed should be such that new capital may be available for extensions and improvements necessary for the proper development of the business.

Business Encouragement.

Some allowance should be made in rate of return authorized as well as in the rate of dividends distributed when necessary, in order that the business may become firmly established with a substantial surplus within a reasonable length of time. It is important to encourage economy and efficiency of operation.

A special effort in this direction has been made in Massachusetts during the last ten years. In 1906, the Massachusetts legislature authorized the adoption of an automatic and interdependent adjustment of the price of gas to consumers and the rate of divi-

dends to stockholders, known as the London Sliding Scale. This system was applied to the Boston Consolidated Gas Company. The standard price of gas was fixed at 90 cents and the standard dividend at 7 per cent., and for every five cents reduction in price an increased dividend of one per cent. was allowed. Under this arrangement, the price of gas was reduced to 85 cents in 1906 and to 80 cents in 1907, and the dividends paid were eight per cent. in 1907, nine per cent. in 1908 to 1913, eight per cent. in 1914, and eight and one-half per cent. in 1915. The subject was investigated in 1915, and the commission reported conditions not satisfactory, insufficient reserve for depreciation, and dividends not fully earned from sale of gas, and further extension of the plan was not recommended. The case was complicated by the combination of various companies, including a holding company, so that no final conclusion as to the advisability or workability of such a scheme was reached. It is, however, a sound business principle worthy of general adoption "that decreased cost and increased profits due to skillful and wise mangement shall be shared in lower prices to the public and higher dividends to the stockholders."

Rate Bases.

Having determined the fair value of the property devoted to the public use and the fair amount of return to be allowed thereon, a third exceedingly difficult problem remains, — namely, the fair distribution of the charges to be made.

Equitable rates are defined as "such as will assess the proper gross income upon consumers without discrimination and with due regard to the public interest."

The two bases of rates are:

1. Cost of service, under which each consumer is charged in exact proportion to the cost of service rendered.

2. Value of service, under which each consumer is charged what the service is worth to him, which in many cases is the price necessary in order to secure an equivalent service. It is a generally accepted principle that each class of consumers shall, so far as possible, bear its share of the costs incurred in serving said class, and pay its share of the profit necessary in order that the rendering

of such service may be a successful business enterprise. The minimum charge cannot be less than the service costs, as business cannot be done at a loss, and the maximum charge cannot be more than the service is worth to the consumer, as he will not pay more than it is worth to him. The adjustment of the rates to the varied types of service may not be determined theoretically, as a perfect theoretical schedule might fail utterly in practice, through the fixing of rates for some varieties of service so high as to be prohibitive. The details of railroad and utility schedules must be determined on business principles and adjusted to local conditions. The object to be sought is the best and largest service possible to all classes of consumers at the lowest practicable rates.

The cost of serving different classes varies widely, as also the value of the service to the customers, and the schedule of rates must recognize the local business conditions in each case.

As in fixing commodity freight rates, the problem often is to determine whether freight rates which will permit the commodity business to be established and carried on are sufficiently remunerative to justify the railroad in rendering the service. So in power service the question often is whether the electric company can supply the power at the rate which the customer can afford to pay or at which substitute power can be obtained with a net gain above the actual cost of rendering the service.

There are a considerable number of earnest advocates of uniform rates on the theory that each unit should be furnished at the same price by the same producer to every customer. On the cost-of-service theory alone, this would sometimes be correct, and it requires very careful consideration in all cases. In electric business, particularly, the cost of rendering a unit of service varies daily. The expenses are practically constant, and the output of units varies. Ordinarily, in a hydro-electric plant a large additional day load may be taken on at slight additional cost. The peak load users are regarded as responsible for the size of the plant, as it is required for their service, and it is the common practice to seek day customers even at much lower rates.

It is an important question of public policy whether exceptionally low rates shall be made for large service, not otherwise available, which would result in large additions to income and

some net profit. Thus far the practice has been very prevalent to make industrial or wholesale rates often without due regard to the cost of rendering the service. This practice requires very careful attention, as there is always danger that the independent large user will not bear his fair share of the cost of rendering service.

Rate Classification.

Schedules of rates should be in such form as to be easily understood, and those for the same class of service should be in the same general form, so that comparison of rates may be made.

The principal types of rates are:

1. Flat Rates.

Under this system a fixed sum is to be paid annually, semiannually, quarterly, or monthly. Flat rates have been based on various conditions of service, such as the frontage of the house or lot, valuation for taxation, floor area of building, number of sleeping rooms, number of persons, and number and character of fixtures. The evident inequalities in all these methods have led to an increasing adoption of the meter system or to the use of the meter as a check upon the inequalities or abuses to which any flat-rate system is liable. The extreme simplicity of this form has caused its retention and present use. When the actual use is for a known time, and also in the case of small users, this type of schedule is found to be quite satisfactory, especially when based on the number and character of the fixtures. But for long and short time users, or peak load and non-peak load users, this form of schedule has been found to be very unsatisfactory.

2. Meter Rates.

Under this system the charge is based on the number of units of service rendered. Uniform meter rates afford a very simple form of schedule, and such a system is satisfactory when the conditions of use are practically the same for all customers. The principal objections to this method are that it does not encourage large use of the service, and that often the price is prohibitive for large business or manufacturing purposes.

Variable meter rates, in which the price diminishes with the

increase of the quantity used in blocks or groups of units, is in most common use in electric, and is frequently found in gas and water rates. Such a system is often made unfair to the long-time small user by making the first block so large as to require all small users to pay the maximum price. In two-block systems the charge for the first block is often made comparatively high, to cover demand or installation costs, and the charge for the second block very low, to induce large industrial or other use.

3. TWO-CHARGE RATES.

This system is based on the theory that each customer is to be held responsible for that part of the operation and plant investment costs necessary in order that the utility may stand ready to serve him, as well as for the number of units of service actually furnished to him.

This system is a combination of flat and meter rates. The flat or " demand " rate bears some relation to the installation or the amount of service which the utility must stand ready to furnish at the demand of the customer, and the meter charge is based on the units of service actually rendered. When the demand charge covers the fixed charges, the service charge is based on the cost of production. The service charge may then be a uniform charge at a moderate price or a variable charge arranged on a block system. A two-block system based on the use of the maximum demand is a very fair and satisfactory system, as the long-time small user is placed on an equality with the long-time large user, which is not the case in a common block system based on the first 10, 20, or 50 or more units. This type of rate is readily adjustable to short-time or part-year service, and is destined to wide use when a simple and accurate method of determining demand is available.

4. THREE-CHARGE RATE.

The cost of conducting utility business may be classified under three heads:

1. Customer charges, varying with the number of customers, such as meter care and reading, billing, postage, collections, etc
2. Demand charges, varying with the size of installation.
3. Service charges, varying with the actual service rendered.

In conducting a large business, it is desirable to arrange expense accounts in these three groups, and this method of classification naturally leads to a three-charge rate. Theoretically, this is the most complete and satisfactory type of rate, but it involves so many practical difficulties in application that it has been adopted by comparatively few companies. It forms the fairest basis for a check on any other schedule of rates when the business is on a large and varied scale. Under this system the bills consist of a comparatively small charge for customer costs, and varying charges for demand and service costs.

Minimum Bills.

The large number of very small users has led most utilities to include a minimum bill in their rate schedules. The object is to prevent dead investment. The minimum bill usually includes customer costs and an allowance for the average amount of consumption by those paying minimum bills. It safeguards, to some extent, the investment and expense involved in standing ready to serve each customer. The justness of such a charge is generally recognized, but there is difference of opinion as to whether it should be a monthly or an annual charge, a flat rate for each class, or depending upon the demand or installation of each consumer. Under a meter system, a reasonable minimum charge is a reasonable precaution against loss. When bills are payable monthly, minimum bills are so collected, but when the actual consumption for the year exceeds the sum of twelve minimum bills it is thought that adjustment should be made on the ground that the object of the minimum bill has been secured.

It seems decidedly unfair for one who pays large bills for ten or eleven months in a year to be charged a minimum bill for a month or two when absent, and this is sometimes provided for by waiving minimum bill on notice of intention to be absent.

Flat-rate minimum bills are in common use, but it does not seem fair to have the same minimum charge for a demand of 250 and 2 500 watts or for a $\frac{5}{8}$-in. and a 2-in. meter.

In a few cases only have state commissions considered the question of yearly or monthly minimums. The Massachusetts Gas and Electric Commission in the Boston Edison Electric case or-

dered a minimum charge to be adjusted on an annual basis, so also the New York Second District Commission in the Buffalo Electric case, and the Maryland Commission in the Baltimore case. The New York Second District Commission said: "The minimum rate should be a yearly minimum and not a monthly minimum. The proper proportion should be charged monthly, however, and an adjustment made at the end of the year." The New Jersey Commission said "that the making of this minimum] charge by the month is just and reasonable and is really more equitable than if the charge were made by the year." The Wisconsin Commission said: "As to whether the minimum bill should be placed on a monthly or yearly basis, much can be said on both sides. In the instant case, however, it seems advisable to leave it on a monthly basis." My present impression is that minimum bills should include something more than actual "customer" costs, and be on a yearly basis.

Discriminatory Schedules.

Before utility rates were placed under commission control, discriminatory rates were universally prevalent, and it is estimated that at least one fourth the schedules now in use violate the long-and-short haul principle. Some of the more common forms are:

Sliding scales, or "step" schedules, in which the larger includes the smaller amount as:

1. "Bills of \$5.00 to \$10.00 — 5 per cent. discount.
   Bills of 10.00 to 15.00 — 10 per cent. discount.
   Bills of 15.00 to 20.00 — 15 per cent. discount.
   Bills of 20.00 and over — 20 per cent. discount.

In this schedule a bill of \$20 calls for only \$16 in settlement, while a bill of \$19.90 calls for \$16.91; a bill of \$15 for \$12.75, and one of \$14.90 for \$13.41, etc. Such schedules are sometimes made less objectionable by adding the proviso that "the maximum charge under any per cent. of discount shall not exceed the minimum charge under the next higher per cent. of discount."

2. "To consumers of less than 50 000 cu. ft. per month, \$1.20 flat per 1 000 cu. ft.
   To consumers of more than 50 000 cu. ft. per month, \$1.10 flat per 1 000 cu. ft."

Under this schedule a consumer using 49 900 cu. ft. pays $59.88, while a consumer using 50 100 is charged only $55.11, i.e., by using 200 cu. ft. more, the bill is reduced $4.77. Such schedules may be improved as above, or by the proviso that "the minimum charge under any per cent. of discount shall not be less than the maximum charge under the next lower per cent. of discount."

Such schedules have been disapproved by various state commissions, and they should be superseded by block or other proper form of schedule.

Prompt Payment Discount.

It is a common practice to adjust schedules to a discount for prompt payment, the rate of discount varying from five per cent. to twenty-five per cent., ten per cent. being most common, and the time limit ten or fifteen days. This appears to be a good working plan, and decidedly preferable to the scheme of adding five to ten per cent. as a penalty, if the bill is not paid in ten or fifteen days following the date of the bill. A sliding discount to large users is sometimes conditional on prompt payment. Such a schedule meets with general disapproval, and should not be allowed.

Electric Rate Schedules.

The development of rate theory and practice already outlined has been mainly occasioned by the marvelous progress in the extent and variety of use of electricity. Since electricity cannot be cheaply stored, it is necessary that the plant equipment be sufficient to generate the maximum demand at any moment. The number of hours of daily use and their relation to the peak load are important in determining the cost of production. It has been estimated that, under certain conditions, it costs two and one-half times as much to furnish a given unit in one hour as to furnish the same unit in three hours, hence it is important to provide for the long- and short-time users in the schedules.

The type of plant, whether the power is water, steam, or a combination of the two, has to be considered. The actual conditions under which each plant operates must determine the type and details of each schedule.

The four principal types of schedules already considered are used by electric utilities, together with endless modifications and variety of details.

Flat rates are usually based on the number of lights installed or the wattage of the connected load, often with some classification as to use. The simplicity and definiteness of this type of schedule makes it popular with many users, but a meter is necessary as a check for any extended use. The prices vary with each plant, and no comparison of rates is possible. Meter rates are coming into general use, except where the amount of service is definitely known, as in street and sign lighting.

Uniform meter rates are principally used by the small companies. The range of meter rates is very striking. The kilowatt sells at from 25 cents to a fraction of a cent, and the question is often raised whether such a diversity of prices is likely to be permanent. In ten years some maximum rates have been reduced from 20 cents to 8 cents per kw. hr. Block meter rates are in most common use, and are very satisfactory, except when the distinction between long- and short-hour customers is important. Large numbers of blocks have been used, but the tendency is to reduce to two blocks, or three at most. Such schedules encourage larger use, particularly for domestic purposes, as flat irons, toasters, etc., when the secondary rate is made sufficiently low.

Examples.

10 cents per kw. hr. for first 20 kw. hr. per month.
4 cents per kw. hr. for excess of 20 kw. hr. per month.

or,

10 cents per kw. hr. for first 10 kw. hr. per month.
8 cents per kw. hr. for next 10 kw. hr. per month.
6 cents per kw. hr. for excess of 20 kw. hr. per month.
Minimum bill, 75 cents per month, or $9.00 per year.
Discount 10 per cent. if paid in ten days.

Demand rates are found to be very satisfactory for extended and varied business. The demand is either measured or estimated in kilowatt or horse-power units. The term " Wright Demand Rate " has been applied to a one-charge rate in which the energy charge is on the block system graded on the demand.

Example.

8 cents per kw. hr. up to equivalent of first 20 hours' use of maximum demand per month.

6 cents per kw hr. for equivalent of next 20 hours' use of maximum demand per month.

4 cents per kw. hr. for excess of 40 hours' use of maximum demand per month.

This form may be extended to any number of blocks desired.

The term "Hopkinson Demand Rate" has been applied to a two-charge rate, consisting of a charge based on the capacity of the customer's installation, plus a charge for energy used. Both the demand and the energy charges may be on the block principle.

Example.

Demand Charge —

$2.50 per kw. for first 40 kw. of the maximum demand, per month.

2.00 per kw. for excess of 40 kw. of the maximum demand, per month.

Energy Charge —

5 cents per kw. hr. for first 1 000 kw. hr. per month.

3 cents per kw. hr. for next 3 000 kw. hr. per month.

1 cent per kw. hr. for excess of 4 000 kw. hr. per month.

The three-charge rate has been called the "Doherty Rate."

Example.

Consumer charge........$1.00 per month.
Demand charge.........$3.00 per month.
Energy charge..........5 cents per kw. hr.

Another type of rates is based on the product turned out by the electric current furnished.

The maximum meter rate for lighting ranges from 5.5 cents to 25 cents per kw. hr., largely from 8 to 13 cents per kw. hr., and the minimum bill is commonly 50 cents, 75 cents, or $1.00 per month, or from $6 to $12 per year. Of the 138 cities in the United States having a population of 40 000 or over, minimum bills are monthly in 90, yearly in 11, variable in 8, and daily in 1. Twenty-four of these cities have no minimum bills, and 4 are not reported.

Power rates are usually very much lower than lighting rates, and various types of demand rates, block, and uniform meter rates are in use. Among the reasons for lower rates for power

are, that it is usually long-hour and off-peak-load service in large amounts, and ordinary rates would be prohibitive.

Meter rates at present are not comparable on account of the extreme variation in maximum rates, and number and variety of blocks.

Street lighting rates have been termed "good-will rates," but they should be determined according to the principles used in establishing other rates. The lamp-year unit is commonly used, and the range of prices is from $8 to $100 per lamp per year, varying with candle power and locality.

Gas Rates.

In the gas business, a comparatively large part of the expenses varies with the amount of product, so that any large waste such as is liable to occur in the use of flat-rate schedules would cause a considerable increase in expenses. Hence a meter rate is recognized as the only satisfactory rate for gas, except where consumption is known, as in street lighting. As gas can be stored conveniently, the peak-load factor is not important in gas rates. Uniform meter rates are in common use, but a block system is often used, including lower rates for industrial and domestic uses other than lighting. The increased use of electricity for lighting is tending to single low rates for gas for other purposes. Gas rates range from 75 cents to $1.50 per 1 000 cu. ft., with few exceptions. Minimum gas bills vary with size of meter, ranging mainly from 25 cents to $1.00 per meter per month, or from $3.00 to $12.00 per year.

Water Rates.

Flat rates still prevail in water utilities, though meter rates are much used. Flat rates are based on the number of rooms, persons, faucets, frontage, and number of stories, assessed valuation or rental value, and meter rates on the daily, monthly, quarterly, or yearly consumption of water. Meter rates are much more just, but the cost of meters, care, reading, liability to freeze in cold climates, liability to leakage, etc., have a strong tendency to limit their use to checking of unusual wastage, unless the water supply is limited.

Meter rates are often uniform, but block rates are used, as in the case of gas, to make lower rates to encourage large use. Two-charge rates may be necessary to meet certain conditions. In a gravity system with unlimited water supply, large amounts may sometimes be furnished at very low rates to the advantage of all concerned. The great diversity of bases of rates and forms of schedules renders any extended comparison of water rates impossible.

The use of water for fire protection is an important feature of water supply, and there is a wide variety of practice in this branch of the business. In a municipally owned plant it is often not taken into account or is regarded as offset by relief from taxes.

In some instances, the full cost is charged, which is the proper method of accounting. The problem then is principally one of valuation to determine what proportion of the plant or amount of investment should be assigned to fire protection.

The Wisconsin commission acts upon the principle "that a water company in supplying the two services — fire protection and domestic service — is entitled to have the cost of these services estimated on the same commercial basis." In the Queens County, N. Y., Rate Case, the principle adopted was "that the company was organized primarily for the sale of water to private consumers for a profit, and the city was entitled to get fire protection at its actual cost as an incidental or surplus service." It is very desirable that the principle of proper payment for fire protection be universally adopted. It is important for municipal as well as private plants, as securing a more equitable adjustment of the costs of rendering the entire service. Meter rates range from 5 cents to 35 cents for 1 000 gal., minimum bill $1 to $12 per year, and hydrant rates from $20 to $60 per year, with few exceptions.

Telephone Rates.

Flat rates are in general use in telephone service. Exchange or base rates usually apply to a radius of from one to two miles or within city or village limits. Residence exchange rates range from $6 to $36 per year, but they are mainly $12, $15, or $18 per year for one or two-party service. Business rates range from $12

to $48 per year, with few exceptions. On rural lines, $12 per year is a common charge, but $15 and $18 per year are being adopted in some localities as necessary in order to maintain proper service. In some cases, stockholders have been allowed reduced rates, but this practice is disapproved by state commissions.

The mileage charge, for service outside the base rate area of the exchange, ranges from 50 cents to $2.50 per year per quarter-mile for different classes of service. Extension bells and sets involve an extra charge ranging from 50 cents to $5 per year.

Toll rates for five-minute messages are applied to zones on the "length of haul" principle. Example, 5 cents for 5 to 10 miles; 10 cents for 10 to 15 miles, etc. In many cases, night service is offered at reduced rates to encourage larger use. Example, — day rate 35 cents, night rate 20 cents. With the necessary improvements in service off the main lines, many of the lower rates are likely to be eliminated.

Measured service for business ranges from 2 cents to 6 cents per message, and block rates are used. Example, — first 600 messages, $24; next 2 400, 3 cents each; excess of 3 000 messages, per year, 2 cents each.

The inequalities in amount of service under flat rates are not as flagrant in residence as in business service, but some limit should be set to the number of messages allowed at a given rate even in residence service. Business service should be largely on the measured basis, as otherwise rates must be well nigh prohibitive for small users. Summer or part-year service presents difficulties which may lead to a two-charge rate involving cost of readiness to serve and of actual service rendered.

Electric Railway Rates.

Flat rates are in use, and the amount of transportation offered for one fare is variable. The most common charge is 5 cents for a zone varying from 2 to 5 miles, but the range is from 3 cents to 8 cents per fare zone. A free transfer covering a second zone is not uncommon. Commutation tickets at the rate of 21 to 25 for $1, and school tickets at about half regular price, are in use in many localities. Theoretically, a rate system in which the same charge is made for a half-mile as for a five- or ten-mile ride is not

satisfactory, and it is an important question whether these rates should be on a strict mileage basis, as is the case in steam railroad rates.

Capitalization.

One of the most important duties of a public service commission is the determination of proper capitalization, especially when railroads or utilities are consolidated or a purchase is made and an increased capitalization is asked for. In connection with such transactions, millions of watered stocks have been issued, and sold to a credulous public. This work still goes on in general, but not to any great extent in public-service corporations. It has been — and is to some extent now — claimed by promoters that surplus common stock is the only inducement adequate to secure money to start an enterprise, the idea being to sell the stock and to make it good by large development of the business. Commissions are making a great effort to prevent the issue of any stocks not representing their face value of judicious investment. If we succeed in this, and can reduce the comparatively few cases of over-capitalization to reasonable dimensions, public-service securities will be among the safest investments. In this connection, Corporation Attorney E. F. Jones said, "I believe every public utility — steam roads, electric car lines, light and power companies, gas companies and all others — ought to welcome a valuation of its property by the commission so as to have a stable foundation for future business." (*Street Railway Bulletin*, December, 1916, p. 542.)

The prevention of leases with exorbitant rentals is a kindred duty of the commission. Any over-capitalization or excessive rentals approved by the commission would appear in connection with dividends or operating costs, and would lay undue burdens on the public patronizing the utility. In case of purchase or rental, the commission does not have simply the two parties to the contract in mind, but also has the public, and the test for every case is whether it is for the good of the whole public.

Discussion.

Mr. Leonard Metcalf. *Mr. President and Gentlemen,* — I had not thought of speaking upon this question to-day, although it is one with which I have had a good deal to do in the last few years.

I have been immensely interested in the presentation the speaker has given. It seems to me an admirable one, fair alike to the public and to the corporation.

It has been my lot to see something of the working of some of our commissions in a more or less intimate way, the commission of this state, of New York, Indiana, Wisconsin, Colorado, and California, and I have come to be a believer in the work of the commissions, as on the whole distinctly to the best good of the public. That means to the advantage alike of the public and of the corporation. There are certain tendencies, however, observable at the present time, which become apparent when we study the work of the commissions in the last decade. Already we are beginning to get together enough experience in the control of public-utility corporations to indicate that we have made some mistakes. After all, the commissions are but human, and it is not to their discredit at all, indeed, it is distinctly to their credit, that when occasion has demanded they have not hesitated to reverse their earlier findings.

I do want to say one or two words in regard to dangers which I have observed, and to challenge one statement of the author in regard to what constitutes a fair rate of return. One of the most useful developments, I think, of the commission control has been the bringing together, about a single board, of the interested parties, with the commissioners or their representatives, the engineers, acting in a sense as a court of justice. In a number of cases that I have observed myself, it has made for good feeling and it has resulted in a prompt settlement of issues with very much smaller cost than would have been involved by litigation.

Similarly, let the commissioners determine the valuation of a property and the fair gross revenue which the property should be permitted to earn, then go back to the corporation, as on the whole probably most conversant with the local situation, and ask it to establish a rate schedule, along certain lines per-

haps which the commission has laid down, which rate schedule should earn the revenue which the commission has laid down as equitable, reserving, of course, to the commission, the right then to revise the schedule prepared by the utility. One of the greatest dangers comes in the transition from one rate schedule to the other, and in that it has seemed to me that the commissions have not recognized the hazard which they were taking and sometimes have not pursued as conservative a course as they might have done with advantage particularly to themselves. For instance, there have been a couple of cases recently in Indiana in which the rate schedule established by the commission failed to earn the rates which the corporation was entitled to earn according to the views of the commission. Now, in those particular instances it seemed to me that it would have been possible for the commission, either through the establishment of a fairly high minimum meter rate, or through making the transition in two steps, to have safeguarded the interests of the corporation, reserving to itself the right to make further reduction if it was found that the rate schedule as first established yielded more revenue than it thought equitable to the public. It would have saved the commission later embarrassment.

A second question which is causing corporations in certain sections of the country — more particularly in the semi-arid and arid regions of the West — a great deal of anxiety, is the question of the position of the commissions on property which is not actively in the service of the public but which has been purchased with a view to the future needs of the public. It is perfectly clear on a moment's thought that on the question of water rights, for instance, if you fail to acquire water rights reasonably in advance of the needs of the community, by the time these needs develop the rights may have assumed virtual monopoly prices. In other words, they may have been put to other uses, so that if you have to condemn them, the contributory damages may be very heavy. For instance, if those rights had been put to agricultural uses, you would have to condemn not only the water but virtually the properties which utilize the water, to the extent to which those properties would have no value without the water. Therefore this factor has introduced one of hazard to the corporation, and

anything that tends to increase the hazard of the corporation, the uncertainty as to its earnings, is to the disadvantage of the public, because the higher the hazard, the higher the necessary rate of return to command the capital needed for the expansion of the property. This question of course bears directly upon the rate-base, because if any of the property is ruled as out of service, then, if it is otherwise unproductive property for the time being, the actual rate of return upon the *entire* property enjoyed by the owners is less than the *nominal* rate of return allowed by the commission upon that portion which it rules as in the service of the public. In this region, that is not so troublesome a factor as it is farther West, and we have had but few examples that have been burdensome. There is the possibility, however, of difficulty in this direction growing out of the acquisition by corporations of drainage areas tributary to their water supplies, on the theory that if those became too expensive they might accomplish the same ends by filtration. The cost of filtration would, of course, be the limiting value of those properties in certain instances from the point of view of the public. But if it be the position of the commissions at a later date that those lands, acquired in good faith for that purpose, should be ruled out as not necessary to the service, it would have the virtual effect of reducing the return to the corporation and thus either do it an injustice or increase its hazard element and thus do injustice to the public.

Now, the principal issue that I would take with the speaker is in regard to the "rate of return" — not as to what the fair rate of return should be, but as to what he indicated might constitute a fair rate of return. I refer particularly to his reference to the "legal rate of return" as perhaps in many cases constituting a "fair rate of return." So far as my observation goes, I believe it to be true that the legal rate of return would not give the public the service which it desires or to which it is entitled. I believe the legal rate of return in this state is six per cent. I do *not* believe that in the average public-service corporation of this state (I speak particularly of water works because I am most familiar with the water-works field, although I have had something to do with the electrical field, having operated some electrical companies),—I do not feel that a six-per-cent. rate of return upon any

valuation which the commission would be likely to find, would command capital in the long run for the development of such a property. It may be in the case of some older, well-established, large corporations, which have surpluses, that they could for a time command the necessary capital on that basis, but in the long run it is my judgment that they could not do so. And I believe that, if they cannot do so, that is evidence of the fact that you would in effect be confiscating a portion of their property if you applied any such rate to them. Of course it is true that when a corporation is established, — has established its credit so that it can borrow money advantageously upon such security as it can offer, — it can borrow its money at a lower rate than can a concern just going into business and therefore not yet having an established business. I believe it to be true, broadly speaking, of such portions of the country as I have seen, and that covers quite a bit of it, that the rate of return which our public service commissions have been allowing water works and some other utilities, is probably from one-half to one per cent. below such a rate as will command capital in the long run. And I believe it can be said justly of certain localities, notably of Massachusetts, of Boston, that we are seeing a declining service at the present time because of the fact that the rate of return is a little closer than it should be in the best interests of the public. Take as an example that of the Boston Elevated Railway. Its stock sold for years under the jurisdiction of the commission, an excellent commission, at varying prices. I do not know the exact average, but I fancy well over par, perhaps as high as 125. Prices as high as 135 and over have been paid; now it is selling at 70 or less. Why? Because in part, perhaps, of the transfer abuse, because of the rapid increase in the wage scale, and the increase in the demands of the public growing out of the subways and other structures, without increase in the rate of return allowed. Now, the mere fact of the stock selling to-day or in the recent past at a price of 70 or thereabouts, stock for much of which a price well over par was given, seems to me to indicate on its face that the earnings have not been quite adequate. The difference is not great, gentlemen.

As applied to the water-works field, what does it practically mean? It means practically this: Would a family prefer to pay

from one half to two thirds of a cent per day additional in order to enable the corporation to earn one per cent. more per annum upon the cost of its property, in order to have a thoroughly up-to-date service, or would it rather not pay that additional amount and have a service which lags after the demand? Practically what it means, what the limiting of the rate of return to too small an amount means, is that the service lags after the demand instead of anticipating the demand. I don't believe that that is wholesome, that it is desirable from the point of view of the best interests of the public, from the point of view of the development of our cities. It tends, amongst other things, to make it more difficult for the public to get a little further out into the country. It circumscribes our freedom somewhat. And I think it is undoubtedly true that the public is much more interested in having a thoroughly good standard of service than in having a slight reduction in the rates. Of course, time alone can tell whether my belief is justified or not, but it at least will be interesting to watch the developments in the next decade. If my surmise is right, if we are seeing a declining service, the next step, which will come certainly within the next decade, will be that these self-same corporations will be unable to raise the necessary money for extensions upon the basis upon which they have heretofore raised it, even with allowance for the changed conditions growing out of the war; and when you have reached that point, the commissions will be face to face with the question whether they will permit the increased rate of return or whether they will still limit it. If the latter, we shall be unable to command the service, and the only outlet would seem to be public ownership of the plants.

With regard to the question of the rate of return, one word more, and that is this: It is distinctly to the disadvantage of the public to have the rate of return too close, for the added reason that the moment that your rate of return does not furnish a return such as to supply from one and a half to two times the coupon interest upon the bonds it becomes difficult for the corporation to borrow. That, of course, touches upon the basis upon which the money has been raised by the concern, but it means practically that the moment you go below a certain danger point by not permitting a margin of safety in earnings, you penalize

the corporation twice: first, by reducing its rate; second, by prescribing such conditions that it can no longer get money upon such advantageous terms as it was able to do theretofore under a somewhat higher rate. Moreover, it leads directly to litigation, and the commissions cannot fail to take into consideration the very heavy costs attendant upon rate suits and upon the carrying of these suits to the courts, for ultimately the public pays those bills. The capitalist does not lend his money in the long run on the assumption that he will pay the expense of those charges. It may be possible temporarily to say that the costs of those suits shall not be included in the operating expenses of any one year, but in the long run economic conditions will control and those costs will be paid by the public. It is not to the corporation's interest, it is not to the public's interest, to have these suits contested in the courts. And I believe we shall see them settled in increasing measure within the consultation rooms of the commissions, to the advantage alike of the corporation and of the public.

Finally, let me say just one word in regard to the surplus issue of stock, the watered stock to which the speaker has referred. It seems to me that there is a different explanation, and a sound reason, for the issuing of surplus stock, a different explanation from which has been made by the author. Is not the theory, underlying the issue of the surplus stock, that time and expense, expenditure of money or sacrifice of dividends, is generally involved in the building up of the business of public-service corporations? I think that it has been the theory that that development expense, as it has been called technically sometimes, had best be taken care of through the issue of the stock. As that expense is incurred, without return to the owner of the property, it is capitalized in stock issue. It has generally involved expenditures and in later years, when the business has developed to such an extent that it could carry it, in other words, pay a return upon the earlier expenditures, then the stock has developed value and reimbursed the owner by dividend payments upon the debt incurred. That seems to me perfectly legitimate from the public as from the corporate point of view. That, I think, is the proper explanation of the issue of surplus stock. I don't mean to say by that, gentle-

men, that stock has not sometimes been issued without reason and in inordinate amount. Of course we all know that it has been. But, on the other hand, it is true that there is sound and fair reason for issuing stock under such circumstances as I have indicated, or to take care of such intangible rights as water rights, patent rights, or other rights of that kind.

Mr. Allen Hazen * (*by letter*). It is always a pleasure to meet old friends in a new field. When "Tute" Worthen was trying to drill "higher" algebra and other mathematical lore into the head of the writer some thirty odd years ago, we little thought that some day his student would be asked to discuss a paper of his on the regulation of rates, a subject not then even thought of. Mathematical training leads to clear thinking, and it is no surprise to the writer to find that Commissioner Worthen has prepared a remarkably concise and clear-cut analysis of this difficult and complex matter.

The writer would suggest in addition or continuation to what Mr. Metcalf has said, that perhaps a little more might be said in regard to rate of return. The writer believes there is one practical and sure final test of rate of return; that is, that it must be sufficient so that as a practical matter all the capital that is necessary will be available to extend the works as needed to afford efficient service.

Efficiency of service is generally much more important to the consumer, as Mr. Metcalf points out, than a small difference in rates. And a five per cent. reduction in rates at a critical point may mean a reduction in the rate of return that, as a practical matter, stops extensions and cripples service.

With reference to the three-charge rate (which logically follows the method referred to by Professor Worthen of classifying costs under three heads) the writer believes that this threefold division probably had its origin in the electric field.

With an electrical equipment there is no storage of the power, and electricity must be generated and carried and distributed to meet the absolute peak-load. Peak-loads in electrical supply are high and irregular, and the cost of furnishing and keeping equipment ready for service to meet these peaks and not other-

* Of Hazen, Whipple & Fuller, Consulting Engineers, New York.

wise needed is a very important part of the whole cost of the service.

With a water-works system, on the other hand, and especially when domestic consumers only are considered, the peak-loads are much less marked in amount and they occur with a remarkable degree of regularity.

In a great many, probably in a majority, of water-works systems, storage of water, connected with the distribution system, is available to help carry these peak-loads. The amount of storage required to cover all of such peaks growing out of regular service is relatively small, and the cost of it is hardly an appreciable element in the whole cost of supplying water. The peak-loads resulting from domestic service are at most only a small fraction of the loads that have to be provided for in supplying fire service. In short, the whole situation of a water-works plant with reference to demand charges is entirely different from that in an electric plant. While it may be admitted that the same principles govern as a practical matter, the writer holds that in a water-works plant the demand charges for domestic consumers are relatively small and may be quite as well distributed into the two remaining classes, with the simplification of the calculations that result therefrom.

This may be less true of the large services through four-inch pipes and larger for railroad and manufacturing uses.

If the consumer charges and the demand charges for domestic takers are considered to be so small that they can be practically ignored, and for the larger services if they are taken at graded amounts which are added to the consumer charges, a series of service charges is reached which in a two-charge rate may be quite as well adapted to distributing the load where it belongs as the more elaborate system of a three-charge rate.

There are, further, some practical limits to the amounts that can be advantageously charged in this way, as the writer recently pointed out in connection with the report of the Committee on Meter Rates.

Mr. Worthen (*by letter*). I will say a further word on rate of return and common stock, which were touched upon in the discussion.

Issue was taken with the use of the legal rate of interest as a working basis for determining the fair rate of net return on the fair value of the investment, subject to modifications to meet local conditions, and the opinion was expressed that in the long run a six per cent. rate of return will not command the capital necessary for the proper development of public utility business.

It is to be noted that the net return for interest and dividends is in addition to proper allowances for depreciation to safeguard the investment and a proper margin for the successful conduct of the business (see topics Fair Return, Depreciation, Rate of Net Return, and Business Encouragement, in the paper).

Public utility business is of a permanent and necessary character, and should be so controlled that communities shall not be exploited by promoters. I believe that public utility stocks should be regarded as permanent investments, and that the approval of a commission should be evidence that each share of stock stands for its face value of actual investment. Public utility securities, when the business is of considerable magnitude, should be available for trust fund and savings bank investments. With the safeguards of commission supervision to secure integrity of investment, efficient operation, provision for depreciation, and protection from irresponsible competition, I think a six per cent. net return on the investment, with a fair proportion of stock and bonds, will command any reasonable amount of capital in most cases, under present conditions. The facts that large amounts of money are being deposited in savings banks paying only three and one-half per cent. or four per cent., and that comparatively few public utilities are now paying more than six per cent. on the investment even when no restriction has been put upon rates of dividend, are important in this connection.

In the matter of "surplus stock," I applied the term only to stock issued in excess of the actual investment, as a bonus. I think that all "time and expense, expenditures of money, or sacrifice of dividends" should be fully shown in the accounting and provided for either in capitalization or amortization, as seems best to fit the conditions.

The paper is only a preliminary study of the whole field, and it affords an opportunity for infinite extension in many directions.

The section on water rates was left especially brief in view of the exhaustive article by Mr. Wagner, already referred to, and the report and discussions on meter rates found in recent numbers of the JOURNAL of this Association.

The commissions as well as the utilities await with great interest the developments of the second decade of public service regulation.

THE EXTENSION OF THE WATER DISTRICT IDEA IN MAINE.

BY HARVEY D. EATON, ESQ.

[*Read September 13, 1916.*]

By a constitutional provision adopted by Maine in 1877, cities and towns can incur indebtedness only to the extent of 5 per cent. of their assessed valuation. Prior to that time, very few places in Maine had installed water works. Subsequent to that time, this debt limit was an effectual barrier to the installment of water systems by cities or towns in their municipal capacity. It therefore came to pass that private water companies practically monopolized the business in Maine, Auburn, Lewiston, Hallowell, and Bangor being the only exceptions, though in the country at large the majority of water plants were publicly owned.

In some instances, supplies were pure and service adequate. In other cases, this was far from true. Waterville, Fairfield, Benton, and Winslow were partly and poorly served with water from the Messalonskee Stream, which was the outlet for the sewers of the town of Oakland. For the service rendered, the rates were high. The works were installed in 1887 following a discussion which lasted several years on the advisability of installing a municipal plant. The debt limit and the natural conservatism of the best citizens and leading business men combined to defeat the far-sighted wisdom of those who wanted the people to install, own, and operate a water system.

Both the cost and character of the service became subject to severe criticism within a few years from the time the works were installed. After some years of otherwise fruitless agitation, the idea occurred to me that a new municipality composed substantially of the territory and people served would not be subject to the constitutional debt limit and would also be a convenient political unit for handling the water business. The necessary legislation was procured in 1899, and in the same year the act was adopted by the people of Waterville and the Fairfield Village corporation

which composed the Kennebec Water District. The company made a prolonged resistance to the carrying out of the act, but final decisions were rendered during the year 1902, fully sustaining the district's rights to take over the company's property.

The actual work of condemnation and appraisal was not completed till early in 1904.

Meanwhile, however, the legislative session of 1903 had granted charters to Augusta, to Brunswick and Topsham, to Dover and Foxcroft, and to Gardiner. Procedure became more speedy as the futility of resistance was demonstrated, and these last-named districts were in actual operation almost as soon as the original Kennebec Water District, which was chartered four years earlier. Other charters followed rapidly, until now this form of organization is found in every section of the state from Kittery to Van Buren.

Portland fell into line in 1907. This district is composed of the cities of Portland, Westbrook, and South Portland, and it also has authority to supply water in the adjoining towns of Standish, Windham, Cape Elizabeth, and Scarboro.

But the system is used not alone by large towns and cities with works already established. Small towns like Anson, Bingham, and Strong, which offered no temptation to promoters or capitalists, have organized water districts, constructed works, and are now enjoying the protection and sanitary benefits of water under pressure.

This brief survey of progress arouses many reflections which might easily lead to more discussion than time permits. A few matters may be worth mentioning. The operations of the original Kennebec Water District have been marked with a degree of harmony and also of financial success seldom met with in actual practice. The board of trustees have held seven hundred and ninety-seven meetings since organization in 1899, and never once has the chairman found it necessary to count a vote. No rule requiring unanimous action was ever adopted, but they began at the outset to defer action till all were agreed, and have always followed that practice. The board of five trustees is appointed by three different bodies from three different localities. The term of office is five years, and three of the five first appointed in

1899 have remained in office ever since. Such continuous, united, and successful work as they have accomplished is a tribute to the character and capacity of this board such as few official bodies ever merit.

In regard to the undertaking as a business proposition, the story may be briefly told as follows: Since the district took over the works in 1904, it has doubled the plant, increased the revenue 70 per cent., reduced the rates, and accumulated a surplus and sinking fund of almost fifteen per cent. of the capital cost.

A prime object in the framing of this charter was to remove the choice of officers as far as possible from the ordinary political scramble. It seems to us that the continuity of service and efficiency thus secured amply justify this method, but we observe that the tendency generally is toward choice of trustees by popular election. Of course this is giving every individual a more direct voice in the management of affairs, but we believe it is at the expense of the highest efficiency. Is it worth while? Surely we would not presume to answer.

Obviously, the water district idea is simply public ownership adapted to the peculiar conditions of Maine. It is nearly fifteen years since the Supreme Court pronounced the plan valid and constitutional in all respects. The largest city and some of the smaller towns have adopted it. Yet an actual majority of all the water plants in Maine are still in private hands. From this statement alone one might be in doubt as to whether the movement was an actual success. But as we note the success, efficiency, and economy of operation, together with the general satisfaction of consumers, and make comparison with communities where private plants still subsist, one cannot escape the conviction that the water district idea was a real blessing to Maine.

THE WATER SUPPLY OF PORTLAND, MAINE.

BY DAVID E. MOULTON, ESQ.

[*Read September 13, 1916.*]

The Portland Water District is one of those peculiar, quasi-municipal corporations that our friend Mr. Eaton conceived years ago. The expressed purpose, and supposedly sole purpose, of a water district, you know, is to furnish water. The real, underlying purpose, however, is to get around the debt limit and enable municipalities to buy water works. The Portland Water District consists of Portland and South Portland, — that part of Portland that is exclusive of the islands in the bay. It supplies water to those cities, and the neighboring city of Westbrook, and six or seven other adjoining towns.

The system reaches from Sebago Lake, some fifteen miles, to the city of Portland, thence along the coast to the east to Falmouth and Cumberland, some seven miles, and to the west, out through Scarboro, some ten miles, making a system in all of rising 250 miles of mains and distribution pipe, supplying a population of practically 85 000 in the territory, of which probably 75 000 are water takers, and having about 15 000 services.

The principal part of our water system is very ancient; in fact, I think it can safely be said to be as old as any city in the world. I do not refer to the ancient cement mains which we have here, although there were engineers found at our hearing who were willing to vouch for their super-excellence and their perpetual life, and I do not know but events are showing that they were right. I refer to the great natural reservoir or settling basin which we have at Sebago Lake.

This lake is one of the largest bodies of pure water known in the world. The lake is some 265 or 270 ft. above mean tide in Portland Harbor, only fifteen miles from the city, and in this reservoir alone there is a water surface of over fifty square miles tributary to the lake, and there are forty-seven other lakes and ponds with an average area of about a square mile each. To be

exact, there are forty-two square miles of water surface in the other lakes, which are all tributary to Sebago Lake, so that there are ninety-two square miles of water surface. Sebago Lake in some places is 360 ft. deep, or 100 ft. deeper than mean tide in Portland Harbor, and there is in the lake eight times as much water as flows from it in a single year. In other words, if it were possible to drain the lake, the Presumpscot River could not only supply the mills on the river, but the water district could use all the water it wants for eight years. That supply would continue uninterrupted if not a drop ran into the lake. It is estimated that less than three inches of the surface water is required for a year's supply to the city of Portland, and there is running off every day from the lake at least 400 000 000 gal., practically enough to supply the city of New York.

All this was ours to start with, and our problem has been not so much to create as to preserve; principally, of course, to preserve the purity of the water, which, in its natural state, is unexcelled for drinking purposes. The upper part of the lake is in a hilly, wooded section; the lower part, cleared more or less; and the water district main starts from the lower bay, about a mile and a half or two miles across. The water district has acquired, for the protection of the water supply, the greater part of Indian Island, the land down to the railroad station, ultimately intending to control the whole of the land upon the lower bay. We have an understanding with the Maine Central Railroad that no structures shall be permitted on their land for the habitation of man, and we have an understanding with the owners of the sawmills which are in operation that as soon as the timber is cut off, the land occupied by them will come to the water district, so that we are practically protected as far as the ownership of land at the lower bay is concerned.

Near our intake house there is a conduit which runs through a rocky rim which holds the waters of the lake. This conduit is about a mile long and leads to a reservoir at lake level. In some places it is 30 ft. below the surface and was blasted through a solid ledge, tunneled through in some instances.

In reading the story of the construction of the conduit, back in 1868 or 1869, I was interested to see that they announced, as a

great event, the fact that a man from New York had been engaged to come and blast with nitroglycerine, something that was practically unknown here at that time, and they prophesied great progress from the new explosive.

To protect this land which the district has acquired around the lake, a wire fence has been built, and all of the land has been fenced to protect it from picnic parties and trespassers. At our intake house, there is a 48-in. cast-iron pipe running 500 ft. out into the lake.

The Sebago basin is a reservoir at lake level at the mouth of the conduit, the water coming down through the conduit, going into the settling basin, as it is called, and then back through the gatehouse to the several mains of the city. In the gatehouse, we have a plant for the hypochlorite treatment of the water. I suppose these plants are familiar to you. There are two concrete tanks in which the mixture is made, and there are automatic devices which lead to the 48-in. mains through which all the water comes before it is distributed to the several mains leading to the city, and by a meter the flow is regulated in accordance with the consumption of the city.

One of the problems that we had was a small brook that ran down through the village of Lake Sebago, near the station. This brook practically took the entire drainage of the village, and it emptied into the lake only about a mile and a half from our intake. The tests of the water invariably showed colon, and all sorts of schemes were devised to protect this brook. There was an old gristmill near the lake, and it was thought to condemn that, but none of these things seemed to be sure to correct the evil, and so finally we decided to construct a plant to sterilize the waters of this stream before it got to the lake. We built on land of the Maine Central Railroad, two years ago, a second hypochlorite plant, and here we treat the waters of the stream. It might be interesting for you to learn the result of this treatment. I think the lowest test showed some 3 000 bacteria, and the best results that we have ever had with the raw water showed that the water was productive of coli in three out of five tests. After treatment, this water will show a reduction of 99 per cent. of the bacteria, and I think there has never been any test showing coli

in the water after it had been treated; so we have practically sterilized the waters of this brook.

There is another little brook near our intake. This is on the shore of the lake, within a quarter of a mile of the intake. There is a small natural watercourse that gets the flowage and drainage from the street. Naturally, that picks up more or less coli in the spring, that being the only time there is water in the stream. We made tests, and found we were getting coli, so, while the brook was hardly large enough to warrant a permanent plant, at an expense of some forty or fifty dollars we built a little temporary plant, and our caretaker at the lake goes down there and mixes that up, and, by a little attention two or three times during the day, he arranges that little plant so that it sterilizes the waters of that brook. It is a very simple operation. We simply use it when the water is running, but we feel that we are getting splendid results from that little outfit.

The Bramhall Reservoir was built at the time of the original construction of the work in 1868, and, along in 1882, one morning it broke out. There was a sort of wall or parapet of stone built around the top of the reservoir, and the water worked along between the stone and the clay puddle, and by frost kept lifting it up, until finally it worked out through the corner, the water being carried in those days within several inches of the top of the wall. So the wall was broken through, but afterwards when this was rebuilt, the parapet was taken off and the water line lowered several feet, reducing the capacity several million gallons, but it has been in use ever since, and is in use to-day, simply as a storage reservoir.

The water system in the city, while built originally for a single high-pressure system, was divided in later years, for convenience, between a high and a low service, and the two reservoirs are now on the low service. Before the new main was built, a standpipe of some 600 000 gal. capacity was built right near the other reservoir on Munjoy Hill, the other reservoir having a capacity of about 20 000 000 gal. This was built to help out the high service, filling up in the night time, and gradually being emptied during the higher output during the day. It was located right beside the Munjoy Reservoir, so the overflow, if there was any during the night, could discharge into the Munjoy Reservoir.

The Munjoy Reservoir also had to pass through its trial, not by fire, but rather by water, and we had quite a calamity there. There was a break in the corner of the reservoir, and perhaps some of you will remember about it. It carried away one or two buildings, and resulted in the loss of one or two lives.

The trouble was found to be in the overflow pipe. This pipe was originally built practically through the center of the embankment, the water found its way alongside the pipe, and finally got out and carried away the fill. It was reconstructed so that the overflow is practically along the surface, and there has been no trouble with it since.

We have a shop on Kennebec Street which was formerly used for testing meters, and which was a legacy from the old water-works company. This building formerly contained our meter department and the bacteriological laboratory, but it is now simply used for a shop and storeroom. We have found it necessary to meet the modern conditions by automobiles, and we have also found that they contribute their share to the high cost of living.

In our laboratory, we test fifteen samples of water each day during the year, and we have been doing this for about three years. While we have found nothing to alarm us in the condition of the water, we treat it, as I have before mentioned, with hypochlorite as a precautionary measure, to remove any chance pollution.

Some three years ago we built a 42-in. cast-iron main to the lake. At the time of our taking over the water works, some eight or nine years ago, it was developed that the capacity of our mains was practically exhausted by the domestic supply, and that we had no fire reserve, so the district was forced to start out and build a new main, and a 42-in. main was constructed from the lake to the city. Practically the whole of the work of digging the trenches was done by a contractor with a digging machine, with very good results on most of the territory. Our other mains follow the highway, but the new one goes practically all of the way over an altogether different route, so that in case of an accident to one, the other will not be involved.

It might be of interest to you water-works men to have some report on our cement mains. The original main was built in 1868,

or started in 1868, and the water turned on in 1870, I believe. This was a 20-in. wrought-iron pipe, riveted cold, with a single row of rivets, and lined with cement. I believe the method of doing that was to stand the shell on end, and pour in a certain amount of liquid cement, and then lower a heated cone in it so it would leave the cement the necessary thickness on the inside, and a coating was put on as it was laid, afterwards. This pipe at the hearing was stated to have a margin of safety of only 2: 2.5 under the pressure it was then carrying. It was quite a question as to the value of these mains. The 24-in. main was built in 1874, I think; several years later, anyway, but of standard riveting. These cement mains have been in use since that time, and while we have no record of the cost of maintenance of these mains previous to taking them over by the district, they have cost us an average of less than $200 a year for each main; that is, the breaks and leaks on them average less than $400 a year for the eight or nine years we have had charge of them. Of course, their carrying capacity is the same now as it was originally. It does seem, for country mains, where they are not likely to be disturbed by the surface work, that they are good for a great many years yet. In cases where we dig to the mains, the cement where it has been recently broken off shows the metal to be bright and clear, and practically as strong as ever; so nobody can estimate how long those mains will last.

At the time the water works was taken over by the water district, a number of the employees came with them, and all of us who have been connected with the district in recent years feel that we are under great obligations to those employees who came to us from the old water company. Many of them had been in the employ of the old company for years, and last year our general manager, Mr. Graham, conceived the idea of having gatherings of these employees to discuss local problems. So we have an organization known as the Portland Water Meeters. They meet once in two weeks during the winter, and some problems are presented to them as to what should be done in case of fire or breaks at certain places. Papers are assigned, and afterwards there is a general discussion, and we have found that the men take a great deal of interest in these meetings and that great good is coming

from them. One of these employees who came to us from the old water company had been with them a great many years, and he could not be prevailed upon to take a vacation until they told him he could use it traveling around looking over the cement mains. So he takes his vacation traveling around and looking over the old mains. It is his special pride to look after them and take care of them, and perhaps that is why they are looking so well. These are types of the good old-fashioned employee, before the days of labor unions, who were willing to stand on their own records for the work that they did. Unfortunately, that type is growing fewer every year, but we do appreciate them while we have them.

I presume a great many of you had the pleasure of meeting the late Millard F. Hicks, the first treasurer of the Portland Water District. He was a member of your Association. I am sure, if you knew him, you loved him, because the pleasure of his acquaintance was a privilege to anybody who knew him. At the time the question of municipal ownership came up, the fact that Millard F. Hicks was the treasurer of this organization gave it the unqualified approval and confidence of every man in the city, because his integrity was beyond question, and we are indebted to him a great deal for the success which the district has had.

The district has been running some seven or eight years, and during that time there has been a steady but not phenomenal growth. The number of services has increased about 20 per cent., and the franchise account, represented entirely, of course, by the construction, has increased from $4 000 000 to $6 000 000, and there has been a steady reduction in water rates, and this in spite of the fact that the district is supplying water to the city of Portland for fire and municipal purposes without any charge whatever.

There is in this connection an interesting feature which is now before us, which has often been before your Association, and that is the question of payments for private fire services. A short time ago that question was raised by the Portland Water District by a petition against itself, in which the district made the claim that the present system of a minimum charge for water was unfair; that is, according to our rules, if a person took a hundred dollars' worth of water, for instance, he, as a perquisite of that amount of

water, should be allowed a private sprinkler system or hydrant service without payment. We made the claim that was not just; it was unfair; it was discrimination, and it was illegal, but that it was forced on us because the claim was made to us and we could not deny it. In our petition to the Public Utilities Commission, these facts were set forth, and the commission has recently filed an order upholding the position of the trustees, stating that the system of charging for private service was unjustly discriminatory and void, and ordering the trustees to file a new schedule of charges, which should be independent of and additional to the charges regularly made for the use of water. That schedule has not yet been filed, but I thought it might be of interest to you, who have discussed this matter so often, to know that the Public Utilities Commission of the State of Maine, at least, has taken the position that the present system is not fair.

While the water district has furnished to the city of Portland water to the extent which at our regular charges would be about $40 000 a year, it has still been enabled to reduce water rates, has increased the investment in the plant, largely represented by the new main, and has also accumulated a sinking fund, so that we feel we have justified our existence.

Perhaps the man who has done most to build up the Portland Water District is Uncle Eben Dyer. Many of you knew him. He was bound up in his work, and a genius in his line.

Discussion.

President Sullivan. There was one thing in Mr. Moulton's paper that struck me, and that was his commendation of the old employees, and the splendid record his company kept of them, with photographs. We do not, in many cases, treat our old employees as they should be treated, and I am very glad to find out that the Portland Water District is going to appreciate and carry in fond remembrance the old men who did the work, before the labor unions got to grade all men alike. There was no grading in the old days. A man was willing to go out all day, night, Sunday, or holiday; would not take a vacation, interested and loyal, and every water works in the country, the older water works particularly, had these men, a type that is fast disappearing.

THE WATER SUPPLY OF MADISON, ANSON, AND EMBDEN, MAINE.

BY LEWIS L. WADSWORTH, ASSOC. MEM. A. S. C. E., PRESIDENT OF THE HANSCOM CONSTRUCTION COMPANY, BOSTON, MASS.

[*Read September 13, 1916.*]

Madison, Anson, and Embden lie in the valleys of the Kennebec and Carrabassett rivers. The towns are progressive and are devoted mainly to manufacturing and agriculture. Power is supplied by large water privileges highly developed, and the agricultural products are as fine as any raised in the state of Maine.

The first organized effort to secure a system for the villages of North Anson and Anson dates back to the winter of 1912, when some prominent citizens secured a charter to form a private water company, to supply the territory with water for domestic use and fire protection.

Surveys were made and a proposition presented to a well-attended town meeting. The citizens were asked to pay the water company an annual hydrant rental of $2 500 for up-to-date fire protection. The proposition was rejected with almost no discussion by the voters, the sense of the meeting being, that when the town was ready for water supply it would install and own its own plant.

The indications for revenue from this territory were good enough to interest private capital, for, in addition to the income from the villages of Anson and North Anson, an additional revenue of $2 500 could probably be obtained from the Madison Water Company. This company operated in adjacent territory and takes its supply from the Kennebec River, which was badly polluted and to-day is condemned.

Each succeeding year the question of water supply was agitated by the citizens. During the winter of 1914, Anson secured a water district charter from the legislature, and in the following spring they accepted the act and voted to build a plant.

Contracts for supplying all material and doing all the construc-

tion were let to the Hanscom Construction Company. They are three contracts in number, and aggregate $165 000.

The plant was started in the spring of 1916, is now 60 per cent. completed, and will be finished before cold weather this fall (1916).

In addition to the revenue which Anson would receive from the takers on their own line, the Madison Water Company, not wishing to go to the expense of securing a new supply, offered to enter into a long-time contract for water to meet their requirements. They were willing to pay $2 500 yearly for approximately 150 000 gal. per day, and offered their reservoir to Anson to take care of excessive demands, as in the event of fires.

As Anson's new system was to be a gravity supply, and large pipes were to be used to give fire protection, they could also supply Madison with water without much, if any, additional cost. The return offered for this service by the Madison Water Company was nearly two thirds of the interest charges on the cost of Anson's trunk line, which had to be built at all events.

The psychological moment then had arrived. A number of the citizens of Anson were quick to grasp the situation, and called a meeting to ratify the contract in hand with the Madison Water Company, to supply that town with water for a long term of years.

If private interests had had the situation to handle, the opportunity would have been seized, but, as is often the case in public affairs, opinions were divided and the project was held up mainly on two issues. The first, that more revenue should be paid by the Madison Water Company, and second, that the pipes were too small. On the first issue the Madison Water Company refused to do more; on the second issue, the leader supporting the claim of small pipes used as his principal argument a two-foot rule on which he held his thumb on the 10-in. mark and left the voters to decide whether or not pipe of that size could supply the water.

As the contentions were sincere, the trustees of the Anson Water District asked for the opinion of Engineer William S. Johnson, of Boston, who looked over the layout and advised that the sizes of the pipes were adequate. He also recommended that the portion of the gravity supply line starting at the pond and running to North Anson, and on which there would be only a few services, be built of wood in place of cast iron. This would effect a consider-

able saving on costs, and the carrying capacity would not decrease during the life of the pipe, as in the case of cast-iron pipe, due to incrustation.

During these weeks of debate and uncertainty in Anson, the citizens in Madison realized that the yearly sum to be paid for water would come direct from their pockets. They acted quickly, stepped in, purchased their system, and refused to enter into any agreement whereby they were to pay to Anson yearly the sum previously decided upon.

The situation then was this: both towns wanted a new water supply and they both wished to work together. They were agreed on a common source, Hancock Pond; neither cared to lay in their own supply line alone, thus duplicating twelve miles of pipe, and indeed we doubt very much if the Utilities Commission of Maine would have allowed this.

Out of this situation developed an idea which to the writer is somewhat new. The trustees knew they could combine their towns and form one water district, and that it had been done successfully in a number of cities in Maine. This, however, was not desired, as under that arrangement one board would have the direction of the water affairs of both towns, and the smaller town would rightfully be in the minority on the board.

The problem was worked out by entering into an agreement whereby both towns were to have joint ownership in the main feed line only. These affairs are handled by both boards of trustees acting as one. Affairs pertaining to their distribution systems, however, are handled differently. Each district has its own board of trustees, collects its own revenue, and decides where to make its own extensions; each makes its own rates or raises money whenever it is needed.

When the citizens of the Madison Water District purchased their system, they decided to make changes to secure high-pressure fire protection, and at a joint meeting of the boards it was agreed, inasmuch as the Madison people were mostly benefited by this change, that they should stand sixty per cent. and Anson forty per cent. of the cost of the jointly owned pipe line.

The system is a gravity system. From Hancock Pond, the source of supply, to North Anson, a distance of seven miles, we are

using a 16-in. wood stave pipe. This wood stave pipe ends just before the distribution system of North Anson begins. There are only a few services taken off this wood stave pipe. From North Anson to Anson there is a 14-in. cast-iron pipe, and a distribution system is installed, as well as at North Anson. The idea of this line is not only to take care of the two villages of Anson and North Anson but also to furnish Madison a new supply. The old Madison reservoir is considerably below the new source, and therefore can be reached by Hancock Pond pressure. This reservoir will not be used, but so connected that, in the case of any trouble with the line, it can be called on as a secondary supply.

W. H. Sawyer, of Lewiston, was engaged as engineer for both districts, and A. F. McAlary took charge as resident engineer.

When the work started, this spring, it was found that conditions governing material and labor were greatly changed since the previous fall, at which time the contract was let. Embargoes on railroads existed, and labor was scarce, high priced, and poor.

It has been said that necessity is the mother of invention, and because of these conditions we are doing eighty per cent. of our digging with a twenty-ton gasoline-driven trenching machine, and filling the trenches with a gasoline-driven traction back filler. The excavator makes rapid progress in clay or gravel ground free from bowlders and ledge. When the latter is encountered, we excavate down to the rock and pass over, resuming full depth when earth is reached again. In hard clay-gravel, a stone the size of the fist will stop its digging, neither can it be economically used in any soil full of fair-sized bowlders. In a few soft, sandy spots, it has pulled out stones as large as a football.

The back filler is sold with the recommendation that only one man be used to operate the machine. We, however, use two additional men on the spoil bank, to set the scraper into the earth at the time the operator draws it toward him. We also find it necessary to clean up with handle shovelers. Progress made by this back filler has always been in excess of any trench we could dig for it to fill when it was not out of commission,—due to breakdowns,—which was often.

At the upper end of the pipe line, close to Hancock Pond, two miles of the wood pipe is laid in a trench four feet deep, through

woods and in ground consisting of nested bowlders. Here we have done away with labor again and resorted to dynamite to do the digging. Half-pound sticks of 20 per cent. and 40 per cent. nitroglycerine are dropped into holes, made with a steel bar, on approximately 3 ft. centers, close to or under the bowlders, and detonated 40 holes at a time. In ground carrying a network of roots, many are broken off and the rest left free from soil so they could be easily and quickly cut with an ax. In all cases, any hard soil in the bottom of the trench was softened up for the shovel by this process. Bowlders containing two or three yards have been shattered without drilling, with 75 per cent. dynamite, by the usual methods of mud capping.

We have found this cheaper and quicker than baring out and hoisting with chain falls, and will continue this method in similar ground even when labor returns to normal conditions.

Before we placed our order for wood pipe, we found conditions not as satisfactory as in the cast-iron pipe industry. Standard specifications for Canadian pine stave pipe call for a class of lumber that is hard to get and rapidly getting scarcer. It is impossible to tell if a knot passes entirely through the stave, as the outside is covered with $\frac{1}{4}$ in. of asphaltic material as well as continuous steel bands. Standard specifications also prohibit large knots, yet they get a bearing against the steel bands and therefore cannot blow out. Specifications call for the steel used in banding to have an ultimate strength of 60 000 lb. to the square inch. On all tests of our pipe, the steel exceeded this amount. The bands are spaced on the pipe on centers to follow the pressure occasioned by the changing contours of the ground, and in this work a factor of safety of four is used, based on the elastic limit of the steel bands as 16 000 lb. per square inch. This is not the practice of some of the manufacturers, as their spacing is based on a factor of four, using the ultimate strength of the steel bands.

It seems wise to the writer to have this extra factor of safety in the bands, for, if it be granted that the wood stave saturated throughout with water lasts indefinitely, then the life of the pipe is the life of the steel bands and they are subjected to continuous moisture.

When relief valves, air valves, or blow-offs are used, the wood

pipe is driven into a cast-iron tee with machined sockets, and the valve is attached to the tee, as is customary in cast-iron pipe practice.

No wood specials were used except when laying to vertical or horizontal curves; then short pieces of pipe are laid which are built to a slight curvature. All wood stave pipe used on the work is of the Michigan manufacture.

If the districts were to let the work under the present prices, instead of those which prevailed last fall, the cost of the material alone would exceed an advance of $22 500.

Discussion.

Mr. M. Knowles.* Mr. Wadsworth says that the wood pipe, under the conditions in which he laid it in the first section, was considered to be the proper thing to lay, and that the specifications under which it was laid, and the requirements, made it necessary to go even a little further than the wood-pipe people themselves thought or suggested to be wise. It would perhaps interest us to know why he stopped at North Anson, and did not continue for the remainder of the supply line, and, if it was wise to use it for the supply line, why could it not have been used for the street lines, and save still further expense?

Mr. Wadsworth relates that it was cheaper to use the trench machine rather than shovels in ground where there was quicksand, even though large quantities were taken out. Will he please tell us something about the slope at which the ground came in, something about the excessive excavation that was encountered. Would it have been at all cheaper, or has he tried to use freezing devices ahead of the machine, to prevent any caving in at all?

Mr. Wadsworth. In regard to freezing devices, the amount of money received for doing this shallow trenching was somewhere around 18 or 20 cents a foot. I have never had any experience with freezing devices, but I think perhaps, inasmuch as we were paid so little, we could not afford to install them. If we have got the work to do, it does not make any difference what we are paid for it, we have to go to the expense of doing it. Where we

* Consulting Engineer, Pittsburg, Pa.

were paid something like 20 cents a foot for the excavation, we succeeded in removing the quicksand to a grade of about four feet, with the machine. It kept caving in; each time it caved in, naturally the banks were a little wider. As we widened out about eight feet, perhaps the banks were two feet high; and then it was a gradual slope to the trench where we laid the pipe. That takes care of four feet of depth. So for the other two feet, we would jump in with shovels, put the pipe right in, and run the joints immediately, thus keeping ahead of the flowing sand.

In regard to using wood pipe on the distribution system, that was considered, and the reason it wasn't used was because of installing the services. The service connections are made by screwing a corporation cock into the wood, and the only thing we have to rely on for that connection with the wood is the slight thread on the corporation. As a matter of fact, where we have made any services, we have not used the corporation screwed into the wood. We have bored a hole through the wood, installed a brass nipple with nuts and washers inside and out, and in that way avoided construction involving the use of a wood thread. I don't know as that has been tried out anywhere else.

The question why we didn't use wood pipe on all the system is a pertinent one. Some of the trustees asked, if we could use it on part of the feed line, why we didn't use it right through. The real reason was this: They had so much money to spend, and while they all recognized that the Ford is a good car, they would much prefer to have a Packard, if they had the money. So the cast-iron line from North Anson to Madison is considered a Packard line, and the wood stave from North Anson to the pond is the Ford line.

Mr. Hawley. I would like to ask Mr. Wadsworth if any test was made on this wooden line for leaking, and if so, what was the result.

Mr. Wadsworth. There has been no test made yet, because, while the line is almost completed, we have not turned the water into it. I can say, though, we have known of several lines that have been properly put together that have actually leaked less than a cast-iron line with lead joints. I speak of lead joints, because there you get the labor of calking, which makes them

tight. We know of joints which have been made with other material, cheaper and tighter than lead.

I don't want you to get the idea that we don't value wood pipe. I believe, with the present price of iron, wood pipe is something that is coming strong. If you were to figure the difference of the cost of our 16-in. main, between wood and iron and the interest on it for twenty-five years (and this line will surely last that long), the amount saved will pay for a new wood line purchased and laid. If these towns had been towns of large valuation, I imagine they would have put in cast-iron pipe, right through to Hancock Pond.

Our line is built of Canadian pine. The specifications called for something which we do not really expect to get; they called for a grade of pine the knots of which do not go way through; and no knots which are large. We have some large knots in it, and we have some small ones, but, as I said in my paper, we can't tell whether they go through, because there is an asphalt coating of one-quarter inch, which covers the knot, and a great many times the steel band will come outside the knot.

We expected trouble from allowing the asphaltic coating to be exposed to the sun for a month before the pipe was laid. We found, however, from the manufacturers, that the Standard Oil Company made a coating that is so soft at first you have to roll it in sawdust, but the heat of the sun, because of the peculiar properties of the coating, does not make it any softer. You can buy pipe and leave it around, as far as the coating goes, and you need not be afraid it will run and become thin on top. Of course, if you leave a wood pipe exposed very much, the staves will shrink. That is the danger of letting it lie around, as you have to, oftentimes, four or five weeks before laying it in the trench.

Mr. McKenzie. In regard to the trench machine, we had some experience in 1911 in laying new main, and it was not an entire success with us. I think in a ground which is plain, or free from roots and stones, it would work very nicely, but in most of our New England towns which are situated a good deal as we are, with unforeseen roots and stones continually slowing the machine, I think the contractor would have done the work cheaper with labor at the price it was at that time, without the machine.

Mr. Fuller. I would like to ask what the expectation is in

regard to the loss of head from friction in this wooden pipe, as compared with cast-iron pipe.

Mr. Wadsworth. I can't answer that question from any experiments, but I believe that the Williams and Hazen hydraulic tables state that wood pipe has a greater loss, due to friction, than new cast-iron pipe.

The dealers (and they seem to be sincere in their claim) use the argument that after the wood pipe has been used a little while, it becomes coated over inside with some sort of a slime, which acts as a lubricant to the flow of the water. In any designs or investigations our office has made, we have always used the same coefficient for wood pipe as for cast-iron pipe.

THE FIRST SLOW SAND FILTER IN THE STATE OF MAINE.

BY HENRY RICHARDS, TRUSTEE OF THE GARDINER WATER DISTRICT.

[*Read January 10, 1917.*]

My appearance as understudy to Mr. Arthur T. Safford, in writing this paper, is due to his suggestion that even engineers sometimes get tired of talking shop, and therefore may be glad to hear occasionally from an outsider.

Whether Mr. Safford is right in his idea, or otherwise, I hardly think that such an everyday affair as the building of a slow sand filter for a little town in Maine could have much technical or professional interest for this Association. But the other side of the matter — the human, social, and, if you like, the political side — is clearly of interest to anybody, anywhere; because it concerns the human relations which underlie, and, in the end, must govern everything we do.

Looking at it in this way, I used the title, " The First Slow Sand Filter in the State of Maine," not because our little filter in Gardiner can lay claim to any historic interest or value from being the first of the kind in the state, but simply because the fact of being first, in such a state as ours, carries with it a whole train of interesting difficulties. For we are intensely individualistic in the state of Maine. We don't like to be told how to do anything — least of all to be told by anybody from Massachusetts, because we can never forget the time when we were the biggest, and (so we thought) most important part of the Province of Massachusetts Bay and the later Commonwealth of Massachusetts. Maine would claim the North Pole by grace of its discovery by Admiral Peary. She would call herself the mother of modern milling by virtue of the Washburn Mills at Minneapolis. And she would assert her determining influence in modern methods of warfare through the work of Sir Hiram Maxim. Wherever things are doing, anywhere throughout the world, you will find a Maine man near the center of activity; and if the good old state fancies her-

self a little because of the triumphs of her sons, it is hard y to be wondered at.

These triumphs have been achieved by men who have gone out from the state, as they have been doing in a steady stream since the first exodus to California in '49. The exodus still goes on. Young men from our high schools go out and win name and fame for themselves abroad, or in our own West; but how about those who are left at home? You cannot draw off your best blood, generation after generation, without affecting the parent stock. Maine is a backward state, paradoxical as it may sound, precisely because of the vigor which has made her a reservoir of ability to be drawn on so freely by others. There is still plenty of vigor left! We are proud of young Holcombe, who left the state years ago, and is, we are told, a hydraulic engineer of international reputation; but we all know that his uncle, old Deacon Holcombe, out at the crossroads, has been the leading millwright of the neighborhood for forty years, and is a far smarter man than his nephew, whose lively career at the high school is still remembered.

There are great corporations in the state, which, of course, do modern work by modern methods, and obtain the best expert advice wherever it can be found. But, when an engineer is called upon to develop a public utility down in Maine, he will at once be up against Deacon Holcombe and his kind, — men of great native ability and much acquired shrewdness, but with no scientific training or knowledge. And the deacon and his kind, we must always remember, carry the votes. Human nature may be much the same the world over, but in a small, backward, and highly individualized community, and when undertaking an operation — like a filter plant — which is the concern of everybody, the engineer must not expect to be *persona grata* because of his retainer, or be surprised to find himself suspected at every turn. From his clothes to his professional fee, from his methods to the scientific data on which they are founded, everything will be questioned, nothing will be taken for granted or accepted as proved. His plans may be regarded with some respect as things not fully comprehended, but the respect will be tempered by a firm conviction that the town surveyor could make a set of plans for twenty-five dollars that would look every bit as good. Why

should a stranger be paid fifty dollars a day when " all there is to it " is a lot of concrete, and everybody knows that the local mason, who does the best concrete work in the county, can be had for five dollars? If the engineer is " on the job " and is paid *per diem*, the cost runs up, and that will never do. But if he delegates his authority to a resident assistant, he is criticized for not being on the job.

The resident assistant is a plain mark for the rapid-fire batteries of criticism. Working from a close specification, watching his unit costs, and judging by results, his way of doing things violates every precedent of local usage and the accepted dictates of common sense. He arranges his machinery, balances his crew, and knows what he is doing, but the picturesque element of bossing is lacking, and every practical man who drops in to see how things are going, bombards him with questions and advice until his only refuge is in silence.

To add to the interesting difficulties to be met in building such a filter as the one under consideration, in a little place like Gardiner, and especially when it is the first to be built within the knowledge of the beneficiaries, there are the really intelligent but uninformed people, who know that no filter is needed because the public water supply has always been the best in the state; those who consider it all nonsense because they can buy a perfectly efficient filter for fifty cents at the plumber's, and those who are sure that bacteria are an invention of the doctors to increase their practice. And when at last the work is done, and the trustees turn on the water to flush out the system, they are met by an excited citizen who has just seen a barrel full of fish that were taken out of the pipes.

As a wise observer said, " The trouble with our people is that they have never been where work is done, and so they don't know how it should be done." The native ability of keen, alert, but untrained minds multiplies the problems, but adds to the interest of such work as this.

And politics? The state of Maine, you know, is a storage reservoir of politics, piped off into every community. I doubt whether Gardiner could ever have had its filter plant, if it had not first adopted commission government. It is the only town in

the state under commission government, and is the first one to have a slow sand filter. The connection, I am convinced, is not fortuitous, but is direct cause and effect. For we are a fighting town, and under commission government the power of the two-party system to choke all progressive endeavor is much weakened, and our struggles have borne fruit.

I have sketched in the human setting of the undertaking at Gardiner, thus briefly and roughly, not only for its intrinsic interest, but as an example and a warning to young engineers, who are never taught in the schools that the human element in any engineering work is more than half the battle, and are often sadly puzzled when they first encounter it. With this introduction I now go on to a more particular description of the conditions and plant at Gardiner.

Gardiner lies on the west bank of the Kennebec River, about six miles below Augusta, and at the mouth of the Cobbosseecontee stream, which has a fall of about one hundred and thirty feet in the last mile of its run to the Kennebec. This situation determined, first, the gathering of Indians, who came there to catch and cure their salmon; and, later, the settlement of white men, who came to trade with the Indians, and remained to build mills and found a city.

The Cobbosseecontee basin has a drainage area of about two hundred square miles, with a storage area of twenty-one square miles in fifteen ponds. There are eight dams (latterly reduced to seven) in the last mile of the run of the stream to the Kennebec, dam No. 8, the upper dam, being the storage or reservoir dam for regulating the supply of water to the mills below.

The Gardiner Water Company, chartered to supply the city of Gardiner and the adjoining towns of Randolph and Farmingdale with water for municipal and domestic purposes, built the present works in 1885, with a pumping station on dam No. 8, and an open reservoir of about two million gallons capacity on a hill a third of a mile from the pumping station, connected with the piping system by a single main. The intake is from the forebay of dam No. 8, and the pumps are driven by the power developed on that dam.

The Gardiner Water Company went through a number of stages of absorption, enlargement, and reorganization, until it emerged

finally as the Maine Water Company, owning and operating plants in many parts of the state. In 1902, the citizens of Gardiner voted to buy the works, and a charter was granted by the legislature to the Gardiner Water District, under which they were empowered to take over the Gardiner plant and franchises of the Maine Water Company at a price to be determined by a court constituted to hear the case. This was done in 1903, and three trustees were elected by the city government. These trustees found themselves facing a serious situation. Like most of the watersheds in Maine, and indeed throughout New England, the drainage area of the Cobbosseecontee, up to this time, had been sparsely settled farming country, with many stretches of woodland, and no sources of dangerous contamination to the stream within thirty miles of the intake. Moreover, the great number and large area of the ponds in the Cobbosseecontee system had furnished a sufficient safeguard against the nearest source of serious pollution at Winthrop. But already the process had begun, which since that time has been going on at such an astonishing rate in Maine, and, in less degree, elsewhere throughout New England. People had discovered the great outdoor world, and cottages, camps, and shacks of every kind were beginning to appear on the shores of every pond and stream — and with them came the motor boats. The probable result of this development was evident from the first, but its rate of progress was beyond conjecture. The water of the stream which had been called the best public supply in the state, was still safe — indeed, excellent — but even at that time the case was well expressed by Mr. Safford, our engineer, who said, "Some day in the future you will have to face the problem of filtering this water."

The trustees had, it will be seen, a serious problem on their hands. To make good all deficiencies and bring the plant up to full efficiency promised to absorb all the resources of the district for some sixteen years, at a time when there was an insistent demand for lower rates. Moreover, this was the time when the responsibilities of public-service corporations were beginning to be better understood, and the trustees soon realized that all reasonable demands for extensions must be met, provided the general income of the district would take care of them. With all this

expense on their hands, the trustees could only "sit tight," while camps were going up on every few rods of shore front, motor boats were multiplying by the score, and the water was being rapidly relegated to the semi-polluted class, meeting the danger as best they could by inspection and regulation.

Problems of water supply in this country usually take for granted an increasing population, but the very slight increase in the population of the state of Maine, for many years, has been confined to the larger cities, while that of the Gardiner Water District has been constant at about eight thousand for decades. The fairy tales of growth, of which we read in water reports, were not for us. But, fortunately, the rule of increasing use of water by regular takers held good, extensions brought in much more income than had been estimated, and the situation was saved. Though rates had been twice reduced, the filter plant, which was no more than a dream in 1910, was undertaken in 1914 and the water was turned on in March, 1916.

The description of the filter plant here following is by Mr. Arthur T. Safford.

In the spring of 1912 the engineer was asked by the trustees of the Water District to visit Gardiner and look over the conditions from the pumping station up the stream as far as Pleasant Pond, particularly the danger of pollution just above the station, and the sources from which sediment from the banks and pollution from the camps might get into the water supply; and at that time he discussed with the trustees the wisdom of carrying the intake above the immediate pollution around the station, which did not appeal to the engineer on account of the expense and the partial remedy it offered. The engineer had acted with the late Freeman C. Coffin for the district in the summer of 1903, at the time of taking over the water works, and, from this previous study of the system and tests of its capacity, was already familiar with its needs.

In July of the same year the engineer sent a written statement to the trustees showing a suggested location for some slow sand filters of 1 000 000 gal. per day capacity and clear water basin of 700 000 gal. along the river below the present pumping station, but which did not occupy the Spear lot. The amount of river

wall and necessary arrangement of the filters, which was not of the best from the operating standpoint, required by the first plans, made the purchase of the Spear lot advisable, and the trustees very wisely obtained title to this lot. In the statement of the engineer, it was estimated that the cost of the structures as outlined would be approximately $74 300, including filters, clear water basin, gravel and sand, pipe, connections, centrifugal pump and river wall, "with the hope of some saving over the figures given." The saving over this figure never materialized, and the work cost just about the figure named. On March 28, 1914, about two years later, after providing the "sinews of war," the trustees visited Lawrence, Mass., saw the operation of the filters there, and soon after made preparations to begin work on the Gardiner plant.

During that spring and early summer the trustees made surveys of the land and dug test pits through the land available for filters, and brought up to date all information necessary for an enlargement to the pumping station and necessary connections between it and the filter plant. On May 29, 1914, the engineer made a further report to the trustees upon the important question whether there was water power enough at dam No. 8, the waterworks dam, to do all the pumping into the system and also lift the water to the filters. The engineer advised auxiliary power in reserve for pumping to the filters and to meet a definite shortage of the power for pumping into the mains which exists now at times of extremely low flow. This shortage amounts to about eight days average per year, in twenty-two years, with one of forty-five days in 1911; but the district has gotten through these periods by economizing on water.

In June of 1914 the engineer was authorized by the trustees to prepare plans and specifications for the new filters, which plans it was intended should be ready about the first of July; but a restudy of the problem, which was only possible through details which were then drawn out for the first time, made certain changes in location absolutely necessary, which delayed the plans until August of 1914, about a month after the time set; but it was the month which was most essential for work if the filters were to be

completed that year. The trustees, however, went ahead just as if the work was to be completed in 1914.

Some idea of the work and quantities involved may be gained from a portion of the advertisement in the *Engineering News*.

I. Sealed proposals for the construction of a covered slow sand filter together with all piping, fixtures and appurtenances, for the Gardiner Water District of Gardiner, Me., will be received at the office of the Gardiner Water District in the City of Gardiner, Me., until 3.00 o'clock P.M. the eighth day of September, 1914.

. . . .

VII. Bids will be compared with the basis of the following estimates of quantities of work to be done:

		Actual Items.
Item 1. Cofferdam and all protection work.		
Item 2. Excavation	7 750 cu. yds.	9 000
Item 3. Rock excavation	900 cu. yds.	2 024
Item 4. Concrete in floors	955 cu. yds.	1 325
Item 5. Concrete in walls	1 280 cu. yds.	1 280
Item 6. Concrete in piers	85 cu. yds.	85
Item 7. Concrete in roof	770 cu. yds.	800
Item 8. Arch centers	27 300 sq. ft.	27 300
Item 9. Cast-iron pipe, 6 in. to 18 in.	30 tons.	24.39
Item 10. Cast-iron specials and flanged pipe	Shown on plans.	
Item 11. Gate valves and appurtenances	Shown on plans.	
Item 12. Controller, regulating valves and indicating apparatus	Shown on plans.	
Item 13. Structural work, ladders, floor plates, supports, and castings	Details furnished.	
Item 14. Interior tile drainage system and roof drains	Details furnished.	
Item 15. Filter gravel	220 cu. yds.	318½
Item 16. Filter sand	2 400 cu. yds.	2 370
Item 17. Entrances and operating chamber	Shown on plans.	
Item 18. Reinforcing material	15 000 lbs.	23 595
Item 19. Exterior tile drainage system	375 ft. 12-in. tile. 50 ft. 4-in. tile.	
Item 20. River wall-concrete	150 cu. yds.	150
Item 21. Seeding	1 acre.	1 acre.
Item 22. Extra work.		

LORING C. BALLARD,
HENRY RICHARDS,
EDWIN L. BUSSELL,
Trustees of the Gardiner Water District.

During negotiations with contractors, there appeared the following difficulties in the way of attempting to complete the filters in 1914:

The lateness of the season; the difficulty in the way of getting sand, gravel, and crushed stone; the amount of excavation required before any concrete could be poured, — the amount of rock being more than twice that of the estimate; the test pits showed simply the low spots, not the high.

For this reason all previous bids were rejected and revised bids called for, opened on October 1, 1914, and the contract awarded to James H. Ferguson, of Boston, Mass., the lowest bidder. Mr. Ferguson carried on the work until June 12, 1915, when much of the excavation was done but little concrete poured; after which time, and under a settlement satisfactory to both parties, the district took over the work and finished it by day labor under the direction of the engineer, during the year 1915.

The design of the filters was based upon the need of filtering approximately 700 000 gal. per day, most of which was pumped during the day hours; a soft, pure water, drawn originally from enormous storage through a comparatively small pond, — Pleasant Pond, — through six miles of shallow stream likely to be overflowed over meadows of fine river silt to dam No. 8, where the 700 000 gal. a day, or the one cubic foot per second pumped into the system with over one hundred other cubic feet for power, is drawn directly from the river into the water-wheel flume. No change in the intake was made in connection with building the filters. There is therefore no chance to settle out any sediment before it is pumped to the filters.

An analysis of the water made in 1911 follows:

Chemical and Bacterial Analysis of Sample of Water from Gardiner, Me., April 4, 1911.

(Parts per 100 000.)

Chemical number	55 361
Bacterial number	7 163
Turbidity	Slight
Sediment	Decided
Odor	Zero
Color	.16

Free ammonia	.0066
Albuminoid ammonia, total	.0152
Albunminoid ammonia, in solution	.0130
Nitrogen as nitrates	.006
Nitrogen as nitrites	.0002
Oxygen consumed	.18
Chlorine	.280
Hardness	1.2
Iron	.0280
Solids — unfiltered. Total	3.3
Loss on ignition	2.1
Fixed	1.2
Solids — filtered. Total	3.0
Loss on ignition	2.0
Fixed	1.0
Bacteria per c.c., 20° C.	12 500
Bacteria per c.c., 40° C. Total	20
Bacteria per c.c., 40° C. Red	6
B. coli, 1 cubic centimeter	0
B. coli, 100 cubic centimeters	0

April 8, 1911.

The growth to provide for was the immediate addition (1914) of South Gardiner and (1915) upper Farmingdale, some increase in population through the district, and the inevitable increased use due to improved methods of living. Ultimately, twenty-four hours pumping will be necessary, and a more rapid rate of filtration than the present one; and finally the general use of meters, all before the filter plant will have to be increased.

The filters and clear water basin, with the superintendent's house, — which hung over the abyss for about one year, — and his barn, which was moved from the site of the clear water basin, occupy about an acre between Central Avenue, the pumping station and Cobbosseecontee stream, about a mile up from the Kennebec River and the business district, the filters — four in number — being at the east or end furthest from the station and the clear water basin at the west end. The north end of the area occupied by the filters and clear water basin is limited by the river; and a heavy concrete river wall was necessary to complete the slopes.

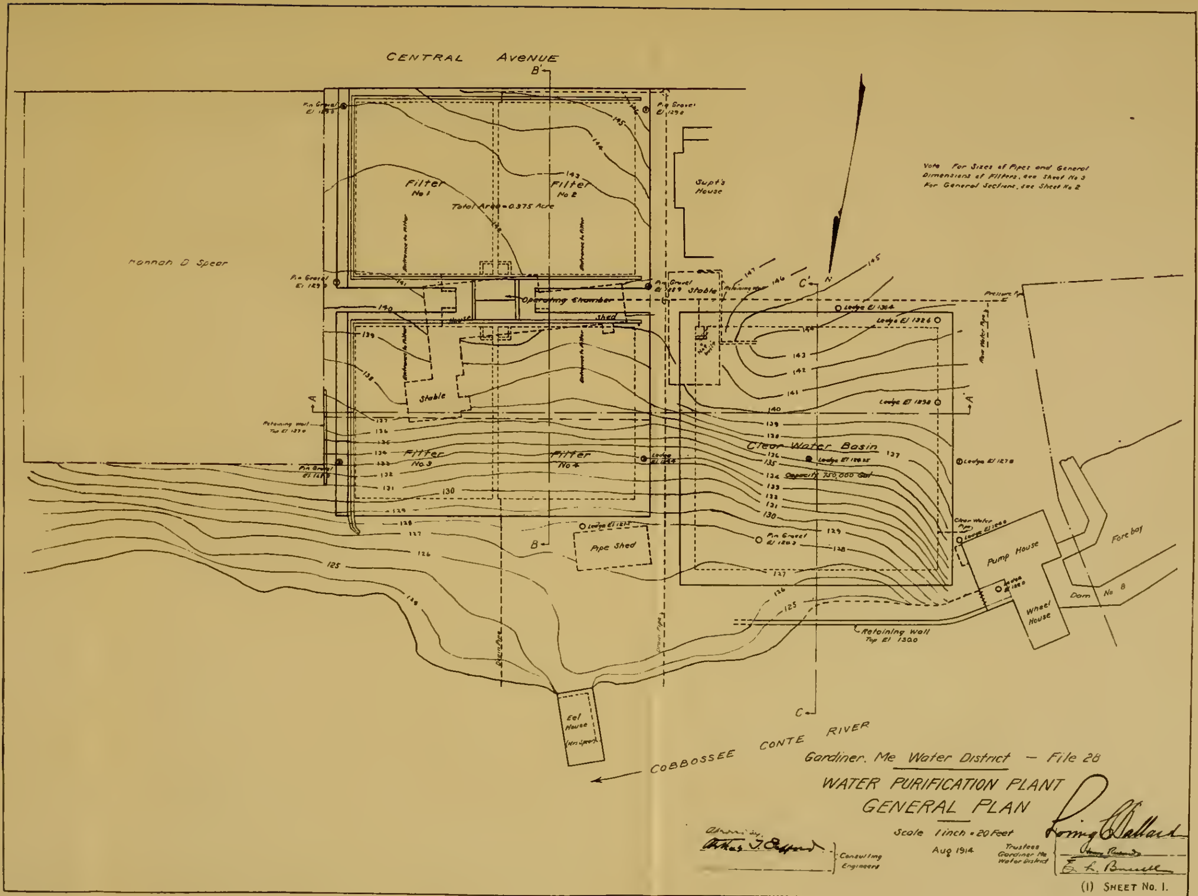
The main supply pipes to the city, and the mains to and from the filters, are all in the lawn and driveway in front of the station

and west of the clear water basin. Connections are made from this point to the operating chamber in the middle of the acre lot between the two filter units and the southeast corner of the clear water basin. The elevations of water are:

High water in the Cobbosseecontee stream above the dam 136.8
High water in the filters......................................144.
High water in the clear water basin.................................137.
High water in the Cobbosseecontee stream below the station ....126.
All above tide water.

The filters consist of four units of 20 squares, each 55 ft. by 73 ft. 4 in. inside dimensions and 12 ft. high. Practically all of filters 3 and 4, the most northerly, were on filled ground. The east walls against the Spear lot are practically vertical walls 10 ft. high, 18 to 24 in. thick, but with broad bases and heavily reinforced against the roof of the filters; the north, west, and south walls are of aqueduct section 4 ft. thick at the bottom. Each pair of filters is separated by a division wall 3 ft. 6 in. at the bottom and 2 ft. at the top and 9 ft. high. All piers are 2 ft. 4 in. at the bottom, 20 in. at the top, the end walls and piers supporting a vaulted roof 6 in. thick at the center of the arch, but carried level over each pier. The bottom is an inverted arch, 6 in. thick. In the middle of each bay are 3 ft. manholes with ordinary iron covers. The clear water basin is 100 by 100 ft. inside, and consists of 49 squares 14 ft. 2 in. by 14 ft. 2 in. The end walls are 12 ft. high of aqueduct section, 4 ft. thick at the bottom, with piers 2 ft. 4 in. at the bottom and 20 in. at the spring. The clear water basin is built on ledge, excepting the three bays nearest the river, which are on fill. In addition to the east wall, the roofs of the filters and clear water basin were reinforced by $\frac{3}{4}$-in. rods in pairs across each other over the tops of the piers.

A 15-in. tile effluent pipe, set in concrete, runs north and south beneath the floor of each filter. This is connected through a 15-in. by 10-in. tile reducer to a 10-in. cast-iron pipe into the operating chamber. Five 15-in. tees, one at the center of each bay, allow water to enter the effluent pipe. Ten-inch split tile drains running north and south and east and west along the centers of the bays bring the water to the tees.


CENTRAL AVENUE
Filter No 1
Filter No 2
Total Area = 0.375 Acre
Supt's House
Hannah D Spear
Operating Chamber
Stable
Stable
Shed
Filter No 3
Filter No 4
Clear Water Basin
Capacity 250,000 Gal
Pump House
Wheel House
Fore bay
Dam No 8
Pipe Shed
Retaining Wall Top El 130.0
Eel House
Note For Sizes of Pipes and General Dimensions of Filters, see Sheet No 3
For General Sections, see Sheet No 2
COBBOSSEE CONTE RIVER
Gardiner. Me Water District — File 28
WATER PURIFICATION PLANT
GENERAL PLAN
Scale 1 inch = 20 Feet
Aug 1914
Consulting Engineers
Trustees Gardiner Me Water District
(1) SHEET No. 1.

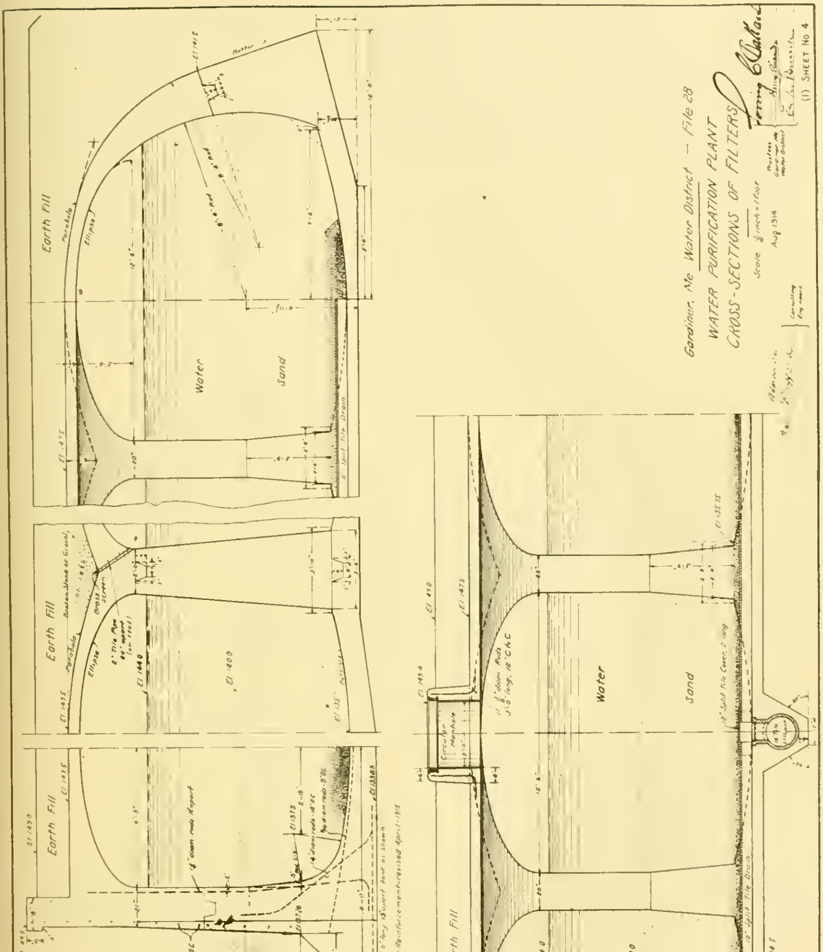


FIG. 1.
CROSS-SECTION OF FILTERS.

The split tile drains are covered with gravel, graded from coarse at the bottom to fine at the top, 1 ft. thick and 6 ft. wide. Above this and covering the entire floor of the filters is a layer of sand 4 ft. thick. This is carefully leveled off at the top, and the raw water stands 4 ft. above the top of the sand.

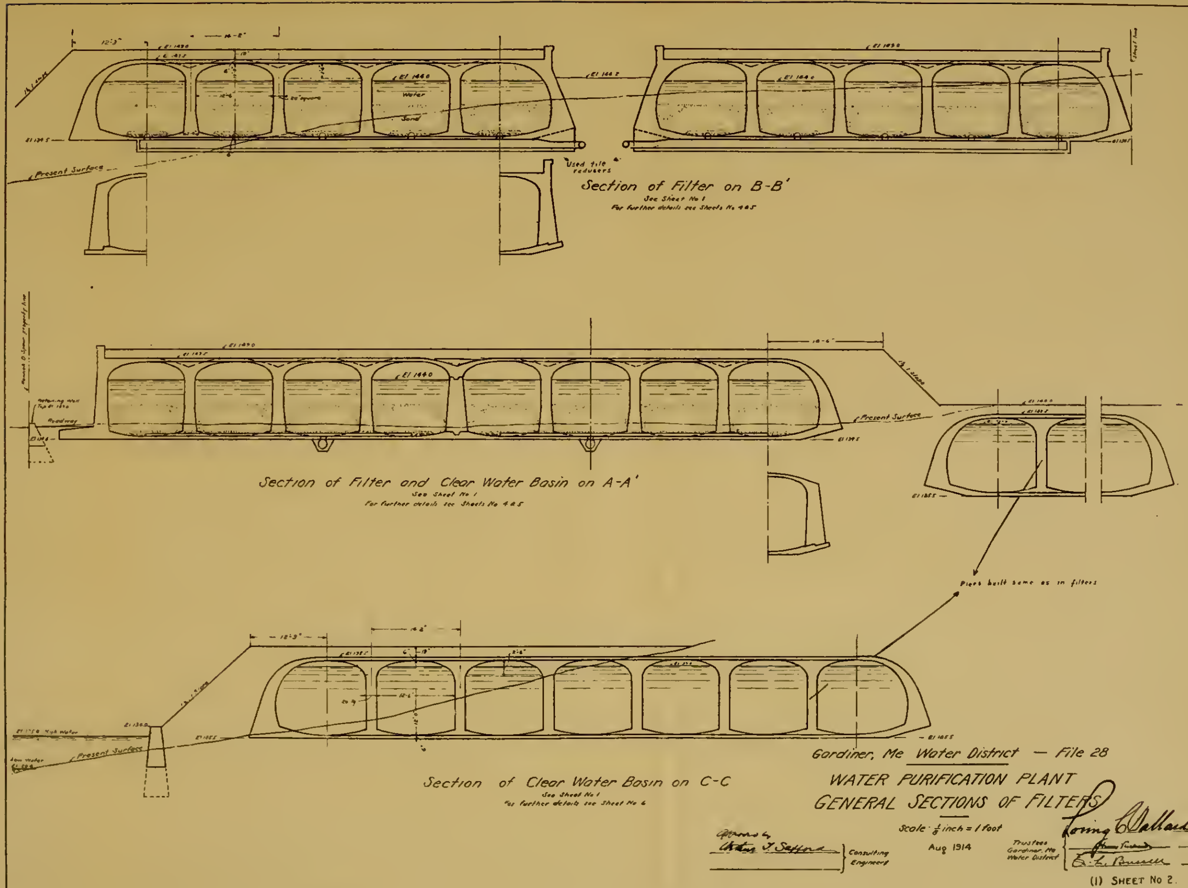
The raw water is pumped from the river by a centrifugal pump through a 16-in. cast-iron pipe to the operating chamber, whence it is delivered to all or any of the filters through 12-in. cast-iron pipes fitted with regulator valves. After being filtered, the water runs by gravity through an 18-in. cast-iron pipe into the clear water basin and from here is pumped either directly into the city mains or to the reservoir by the two pumps in the station.

The operating chamber contains all the valves to regulate the flow of water into and from the filters. It also contains gages (of the clock type) registering the amount of water filtered and the rate of filtration. This is done by means of Venturi meters set in the 10-in. cast-iron outlet to the effluent pipes.

The runways into the filters consist of three 3-in. by 8-in. hard-pine planks, 18 ft. long, supported at the upper end by a concrete sill and at the lower end by a 6-in. $12\frac{1}{4}$-lb. I-beam with its ends set in the concrete of two adjacent piers. The lower end of the planks is level with the top of the sand in the filters. This runway and the operation of cleaning were made as simple as possible due to the very infrequent cleaning necessary for some years.

The general design of the raw water and effluent systems is similar to that in the Lawrence, Mass., filters, and there are no special problems of design which have not been worked out successfully elsewhere. The problem was particularly one of getting materials to the spot and of building filters on that location suitable to the needs of the district and which would be ready for immediate use when finished, without the usual experimental period.

Friendly suggestions were given the engineer by old business associates, Mr. Harry W. Clark, of the Massachusetts Health Department, and Mr. William S. Johnson; and his assistant Mr. Guy S. Deming carried on his shoulders the responsibility of the work.


Present Surface
Used tile reducers
Section of Filter on B-B'
See Sheet No 1
For further details see Sheets No 4 & 5
Water
Sand
Present Surface
Section of Filter and Clear Water Basin on A-A'
See Sheet No 1
For further details see Sheets No 4 & 5
Piers built same as in filters
Present Surface
Section of Clear Water Basin on C-C
See Sheet No 1
For further details see Sheet No 6
Gardiner, Me Water District — File 28
WATER PURIFICATION PLANT
GENERAL SECTIONS OF FILTERS
Scale 1/8 inch = 1 foot
Aug 1914
Consulting Engineers
Trustees Gardiner, Me Water District
(1) SHEET No 2.

Mention has been made of the difficulties in the way of getting materials. As finally selected, they were as follows:

4 550 barrels Lehigh cement at a price of $1.68 a barrel in Gardiner.
3 370 cu. yd. stone from within two miles of the job, hauled by teams and crushed at a final cost of $0.88 per cu. yd.
2 025 cu. yd. sand for concrete, screened, from the Haley bank and landed on the job at $1.23 per cu. yd.
2 370 cu. yd. sand for filters from Merrymeeting Bay, dredged, brought in lighters, and hauled to job at a final cost of $1.95 per cu. yd.
318½ cu. yd. of selected gravel around the underdrains and landed on job at a cost of $5.72 per cu. yd.

The 3 640 cu. yd. of concrete were placed at a total cost of $30-079.09 and an average price of $8.26 per cu. yd., the excavation cost $6 935.75, or $0.77 per cu. yd; the rock excavation, $4 552.88, or $2.25 per cu. yd.

The ground water flow was picked up by a 12-in. exterior tile drainage system and carried to the river.

At the time the district took over the work, after nine months, most of the excavation had been done, but only 337 cu. yd., or 9.2 per cent., of the concrete had been poured, and this the roughest part in the bottom of the filters. There was left on the work certain apparatus (most of it insufficient), supplies, forms, pipes and specials, all of which were inventoried and paid for. The basis of the settlement with Mr. Ferguson was businesslike to the extreme; the trustees paid him for what he did, at his contract prices, and bought his materials for what they cost him.

The trustees, between July 8 and July 19, 1915, cleaned up and made safe the job; bought necessary supplies, revamped the contractor's old outfit, and built new apparatus, runways for landing sand and stone, and completed the job, including most of the additions to and connections with the pumping station, in twenty-five weeks. No portion of the work was faulty, excepting the few cracks to which Mr. Richards refers below; nothing had to be done a second time and, with rising prices for materials and labor, the work has been completed and the filters started for the sum of $71 000, not including some credits.

For the future there remains to operate the filters to the best advantage and in the best manner, which can only be found out

by trial; to bring out the filters to their fullest capacity; and by constant chemical and biological analyses keep the filters in the best condition to free the water from pollution and make it as palatable as possible.

In the judgment of the engineer, the only problem which remains is an excess of sediment in the raw water at certain times in the year. This may not overtax the filters for some years, but is likely to cut down their capacity very materially for short periods of time. The remedy is a simple one: to change the intake, which now being in the current to the water wheel is in a place where all sediment of all sorts is drawn towards it, to a location a little further upstream and behind a timber crib or concrete bulkhead, so designed that all the water pumped to the filters shall be drawn from a middle level, neither top nor bottom, after most of the coarse sediment will have been deposited. This bulkhead may be arranged in such a way that the water can be cut off and the sediment removed from time to time.

Additional filters and continuous pumping twenty-four hours in the day may come, in spite of meters, if the population of Gardiner increases materially in the future, but such an increase will bring with it increased revenues, and there is nothing about the filters or the present location which will prevent extending or using the filtration plant for a larger consumption of water.

If there is much pumping to the reservoir during hot weather, the reservoir may have to be covered.

[At this point Mr. Richards takes up the story.]

A few points remain that may be of interest. Sand for local use is brought up river from Merrymeeting Bay — in effect, a great shallow lake in which all the detritus brought down by the Androscoggin River is deposited at its junction with the Kennebec. It had been supposed that clean, sharp sand of almost any required grain or grading could be obtained from this source, but this proved entirely unsuitable for concrete, and after testing samples from a wide range of localities, satisfactory sand for concrete was at last found in a bank built up of river dredgings, deposited by the Federal Government a couple of miles below South Gardiner. It is worth noting, perhaps, that of a dozen or so of

these banks, deposited at various points below Augusta, this one alone gave satisfactory results.

While the question of sand for concrete was still unsettled, the contractor, a rather headstrong person, with more zeal than discretion, landed a large quantity of "Bay" sand at the site on his own responsibility, and this sand was a bone of contention for many weeks. Being conveniently at hand, it was tried as filter sand in the model filters in which the problems of filtration were being worked out, and showed decidedly better results than the specification sand prepared for the purpose.

The results thus outlined suggested, first, the great need of sand graded to specification at a reasonable price. Such grading as is done seems to be prohibitive in price, or, for various reasons, is not to be depended on. The lack of a material exactly suited to the specific purpose in hand is the secret of much failure in concrete. The results described suggest, secondly, the question whether the considerable percentage of mica, present in the "Bay" sand, which was the probable cause of its failure in concrete, may perhaps have been the reason, or one of the reasons, for its success as filter sand. To the writer, it seems reasonable to suppose that flakes of mica of the right size and in suitable proportion might possibly serve as accessory agents to the *schmutzdecke* in retarding the flow through the filter and increasing its efficiency.

Some experience with cracks in the concrete may be not without interest. A contraction crack in the roof of the clear water basin was not unexpected and was easily taken care of. A second crack,— possibly a "cold shut" between two layings of concrete, in the wall between filter No. 1 and the controlling chamber, took care of itself in a short time. But two cracks in filter No. 3 were rather inexplicable, and caused some trouble. One of these cracks appeared near the west side of the roof of this filter, extending across the roof to the eastward, opening to about three eighths of an inch in the parapet, continuing down the east wall, and dying out near the toe of the wall. As this crack showed lateral without vertical displacement, it might have been due to insufficient filling on the north side (the filling on this side was incomplete and not well packed when the filter was filled), but, unfortunately for this theory, there was a second crack in this same

filter, which outlawed it. Neither of these two cracks appeared until after the filter was filled with sand, nor was the second one suspected until the filter was in operation on a flush-out run, when daily samples of effluent water were being sent to the State Laboratory, bringing regular reports of B. coli from filter No. 3. This most unexpected and unwelcome development furnished much food for thought, until finally the suggestion of a crack in the bottom of this filter explained the whole matter. The filter was drained, the sand was shoveled back, and the crack was discovered in the floor, almost immediately below the crack in the roof just described. This second crack began in the partition wall between filters Nos. 3 and 4, near the surface of the sand, extending down the wall, well across the floor, then turning and running out through the north wall. Ground water from the rotten ledge underlying the filter had come in through this crack, explaining the presence of B. coli, but any movement that could have caused the first crack was negatived by this one. The conclusion was that both were contraction cracks, caused, possibly, by the exposure of the unfilled filter for many weeks to extremely low temperatures.

After many experiments it was found that the cracks were most effectively stopped by calking with lead wool. Wisdom after the event suggests more horizontal reinforcement in the outer walls, and ample reinforcement in the floors of the filters.

Our experience in cleaning filters may be worth recounting. The filters were turned on March 24, and the practice of running three filters, with one in reserve, has been followed from the beginning. The first partial clean-up was made June 3, when the surface of the middle sections of all the filters was loosened up and some of the *schmutzdecke* was removed. Filters No. 3 and No. 4 were thoroughly cleaned, September 15. October brought heavy rains, and the raw water was loaded with silt. All four filters were cleaned November 1, when half an inch of mud was found on top of the *schmutzdecke*. The filters are now expected to run without further cleaning until April 1.

The practice in cleaning is to drain the filter, let it stand three days for the *schmutzdecke* to dry, when it is very easily removed with flat steel shovels. The surface of the sand is then loosened

up and leveled off with steel rakes, and the filter is ready for work. The total loss of sand from cleaning since the filters were started is little more than one inch.

In conclusion, I should add that the results obtained from the filter are better than was expected and all that could be asked. The reduction in bacteria count has been ninety-eight per cent. almost uniformly. The removal of objectionable flavor has been very satisfactory. The reduction in turbidity, even under the worst conditions, has exceeded all expectations. Perhaps the best comment on the whole operation is found in the facts that the Hazzard shoe factory, employing sixteen hundred hands, which formerly paid a local spring-water man so much per capita per week for a supply of drinking water, has now put in bubbling fountains, and is using filtered Cobbossee water with marked satisfaction,— and in the change from almost unanimous popular condemnation of the filter and all its works, with the men responsible for it, to an equally unanimous chorus of praise and congratulation.

One further point has been noticed. Since the filter was started, the growth of "tubercles" in the water-ways of our 12-in Blake pump has decreased something like ninety-five per cent , and if there has been anything like an equal reduction of interior concretions in the cast-iron pipes, the effect is significant.

Discussion.

Mr. A. T. Safford.* I am not going to say very much this afternoon because the discussion I agreed to give has been written into the description of the filter. You must have realized, in hearing this paper, how much has been done by the trustees of the Gardiner Water District in preparing the public for an improvement like this.

There is no question in my mind that the Cobbosseecontee stream is about as good for water supply purposes as you would expect to find, certainly out of Massachusetts. And I question, if the trustees had let this supply go on without filtration, whether they would have been very seriously censured. Usually it takes

* Consulting Hydraulic Engineer, Lowell, Mass.

an epidemic of typhoid to start the public. The best thing about the Gardiner plant as a first slow sand filter in Maine is that all these surface waters in time will have to be filtered; and now, when a municipality in Maine wishes to talk about filtration, they can point to the fact that the city of Gardiner has made the start, has made it successfully, and paved the way for a great many other filters.

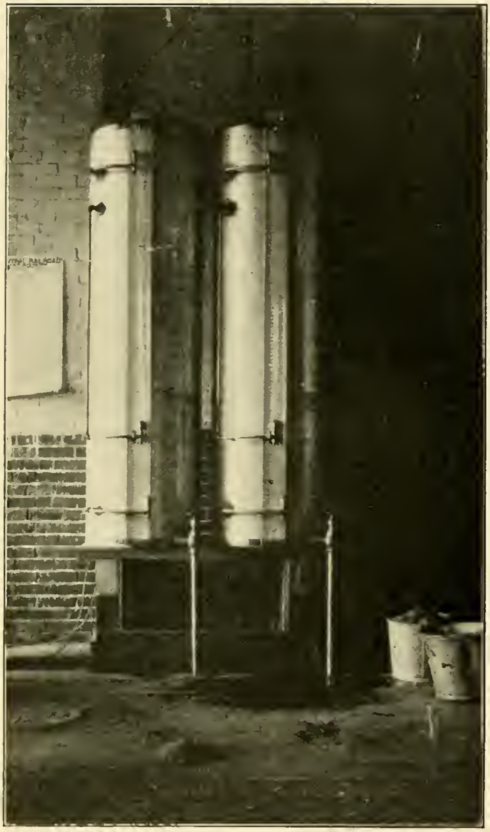
Some description of the experimental filters may be interesting.

These filters or tanks, made of galvanized iron, were exactly similar in design, 6 ft. high and 20 in. in diameter. There were three taps for loss of head gages arranged to give the loss of head through the upper three inches of the sand layer and through the total depth of the sand. The water supply to the tanks was controlled by ball-cocks, and the rate of filtration regulated by the effluent valves. In order to approximate as closely as possible the operating head which would obtain in the filters themselves, without building the test tanks to the full height of the filters, the effluent pipe was extended down about three feet and sealed in a pail of water from which the overflow lead to a sewer. By employing the principle of the draft tube, the height of the tank was kept down to a convenient figure. The two tanks, fittings, gage glasses, all set up ready to receive the sand, cost about fifty dollars. (See Plate VI.)

One of the tanks was filled with sand, furnished and graded by Green & Wilson, of Waterville, Me., to conform to the specifications for filter sand (practically the Lawrence, Mass., specifications). The other tank was filled with the so-called "Bay" sand, which the contractor had delivered on the job and which, bought for concrete, was rejected on account of the excess of mica.

The lower six inches of each tank was filled with coarse, clean gravel, and the sand carried up four feet to a level about half way between the upper two gage taps.

While the engineers were at work planning and testing out the experimental filters, we had a great deal of assistance from Mr. Richards, whose occasional picturesque criticisms kept the problem clearer before us. Without his permission I give a portion of an interesting letter from him which was received during the preliminary work of the experimental filters:



VIEW OF EXPERIMENTAL FILTERS.

"The experiments which Mr. Deming is trying with the model filter seem to be directed exclusively to determining the capacity of our filter plant. They will show — in fact, they have already shown — that with clean 'specification' sand we could run an enormous amount of water, in excess of our needs, through the filter. Later on they will show the rate of slowing down, and the time required, under different conditions of raw water, to reach the minimum fixed by our consumption. They will also show the comparative capacity of 'specification' and 'Bay' sand, under the changing conditions from 'free' to 'choked.'

"All this is good, so far as it goes; but, when all is done, it will show only that the rat can get through the hole, which we soon determined, and it does not prove that the material we are using is in any way better than chicken-wire or paving stones.

"The essence of the whole business of filtration, as I understand it, is in the bacteriological action that occurs in the filter bed, and I suppose there must be certain well-determined relations between the rate of flow and the gage and grading of the sand that are essential to the development and maintenance of this bacteriological action. If this be true, and since our rate of flow is fixed by our consumption, the point seems to be to determine the gage and grading of sand that will maintain the bacteriological action under our constant flow when the sand is clean and maintain the flow to reasonable limits of choking. There you have a range, say, from *a* to *b*, which should be expressible in gallons per minute, per square foot, or whatever, within which we must keep if we would have the filter effective."

The tanks were first set up in the water board office, and a number of preliminary runs made to test the apparatus. On April 14, 1915, during the spring, when the work of pouring concrete for the filters was really begun, the two filters were drained, dismantled, and moved up to a new location at the pumping station, where they were supplied with raw water directly from one of the main supply mains at a point just beyond the check valve. On April 19, the two filters were again in operation at a 3 million gallon per acre daily rate. On May 3, samples of raw water from the pumping station forebay and the effluent from each of the test filters were collected and sent to the State Laboratory of Hygiene in Augusta, for analysis. The analyses showed positive tests for B. coli in 1 c.c. of the raw water, and a warning notice to boil the water was published in the local newspaper. The effluents of the two filters were good and the percentage of bacteria removed high,

considering the short time the filters had been in operation. (Analyses on page 224.)

The filtration rate was then increased to 4 million gallons per acre daily, and further analyses were planned for, to determine whether or not the new rate was too high for efficient filtration.

From May 8 until May 25, 1915, the two test filters ran at a rate of 4 million gallons per acre daily, when the rate was increased to $4\frac{1}{2}$, and on May 26 to 5 million gallons per acre daily. On May 17, samples were collected as before and analyses made by the State Laboratory of Hygiene. Neither of the filters showed any signs of breaking down under the increased rate, though No. 1, containing "specification" sand, indicated greater biological activity than No. 2, containing "Bay" sand. The removal of bacteria at 37.5 degrees was 98 per cent. for each. The maximum total loss of head to date (June 12, 1915) in No. 1 is about 0.68 ft., and in No. 2 about 1.04 ft., each filter showing a gradual increase.

By the settlement between the trustees and the contractor, the former agreed to take the 644 cu. yd. of "Bay" sand which the contractor had delivered on the job but was rejected for concrete. The performance of test filter No. 2 indicates that this sand could probably be satisfactorily utilized in the filters, and the tests carried on without interruption throughout the summer and fall gave no reason to alter this conclusion.

SOME PROBLEMS OF WATER SUPPLY SANITATION IN NEW HAMPSHIRE.

BY CHARLES D. HOWARD.*

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New Hampshire is fortunate in the natural excellence of its public water supplies. Of slight coloration, extremely low mineralization, with relative freedom from troubles due to microscopic organisms, and the lesser risk of contamination inherent in more populous sections, those of the Granite State are, as a group, unexcelled.

Where, in New England, can one find a finer water system, or a more remarkable source, than the flowing artesian supply of the Pennichuck Water Works at Nashua, — President Sullivan's system. Continually boiling up out of the ground is soft spring water, in quality unexcelled by any water anywhere, and in quantity supplying a whole city. While we must admit that there are, unfortunately, a few supplies of which we are not proud, yet we feel justified in claiming that, as a result of the application of some form of treatment, there is not one at the present time seriously liable to be a direct cause of disease.

Sanitary control of water supplies was effected by the state board of health in 1902, with the establishment of the state laboratory of hygiene. Sample collections are made of the various supplies a number of times each year, those from some of the larger systems averaging once a month, or oftener. In addition, numerous watershed inspections are made and advice given as occasion arises.

Out of a total of 116 public water systems, sixty-two, or slightly over one half, are derived from surface sources, the latter in most cases representing natural or artificial ponds or lakes. While the small impounded woodland or mountain brook is frequently resorted to, streams of a size to warrant the name of river consti-

* Chemist State Board of Health, Concord, N. H.

tute a regular source in some three or four cases only, and in but two of these is the water appreciably subject to contamination, a purification treatment being applied in each instance.

It must be admitted, however, that, in the case of the systems using ground water, practically all of these have an emergency intake in some pond or stream. We realize that these emergency intakes, no matter how infrequently they may be resorted to in practice, constitute one of the problems of insuring a continuously pure water supply. It is true that a large share of these secondary sources are passably good; yet a lot of them are not, and even though these may be requisitioned only in case of an extensive fire, or for brief periods of unusual shortage, the desirability of a system of check and control in such cases by a central authority is recognized by our department.

Approximately 45 per cent. of our public systems are municipally owned. Of the 55 per cent. privately owned, most are small supplies. It seems to be our experience that the supply under private ownership is apt not to be a good thing for the consumer, although this is not nearly so true to-day as it was a few years ago. One such company was recently put out of business because of failure to heed the murmurs of its patrons and its unwillingness to expend a few thousand dollars for the installation of a quite indispensable filter-plant for the removal of excessive color. One or two other companies are likely eventually to find themselves in a similar predicament, due to the same reason. Consumers everywhere are becoming more critical as to the physical character of the water they drink, and the prediction is ventured that the day is not far distant when it will be demanded that all of our public supplies shall have the general attributes of spring water.

Relatively few of our waters are, however, concerned with the color problem, and difficulties due to odor and taste, although arising now and then, are generally of very limited duration and have never proved especially troublesome. Turbidity is of course something we know very little about. Practically the only sources whose natural turbidity approaches in any material degree to that so generally true of the streams further west are those of Exeter and Newmarket. The former is satisfactorily cared for by

mechanical filtration, with chlorine gas as an auxiliary to alum flocculation, while plans are under consideration for a similar treatment in the latter case. In common with quite a number of municipalities, the town of Newmarket recently sought to get around some of its troubles by resorting to the expedient of deep drilled wells. The result was hardly a success, however, as the quantity was disappointing and the water carried a considerable alkalinity, due to bicarbonate of soda.

Another village which had a decidedly unsatisfactory experience with the deep-well proposition is that of Salmon Falls. This is a compactly built mill town of about 1 500 population, at present rather unique in the respect that it is the only place in the state of any size which does not possess a modern public system, the tenement dwellers being dependent upon a number of sidewalk pumps. A few years ago, in an attempt to improve both the quality and increase the quantity available from these sources, deep drillings were made at the bottoms of three of these wells. Due, however, to the seamy ledge, no improvement whatever resulted over the polluted condition existent in the original wells.

Although it is our experience that a not inconsiderable proportion of the deep wells constructed during the past few years have resulted in an iron-impregnated water, yet it so happens that thus far none of these are a part of any public system. As a rule, our uncontaminated ground waters are very free from iron. Although there are four or five public systems that have a slight amount of trouble at times from this metal, practically there are but two in the state which have given their superintendents cause to really know what iron contamination is like.

Some years ago a number of shallow driven wells were constructed as a supply for the village of Merrimack. The water proving impossibly ferruginous, the company reverted to the original Souhegan River source. When the latter was condemned recently by the state board of health, the matter of utilizing the water of these wells was again taken up and eventually a deferrization treatment installed which involves passing the aërated raw water through a coke filter and subsequently through sand. Although the source is quite rich in iron, the results have been very satisfactory, the removal averaging not far from 95 per cent.

Equally satisfactory iron removal is effected in the case of the Dover supply, which consists of a combination of pond water and ferruginated springs. The latter issue from an iron-bearing sand which is overlayed by a rich muck. At times of rains not only is the iron content increased, but a troublesome acid condition has developed. During 1909 a slow sand filtration plant was installed, partly for the removal of iron and partly to insure the purity of the pond water. The mixture of pond and spring water travels a few thousand feet before entering the aërator, which is of the perforated iron plate type. One beneficial result of premixture with the pond water is that flocculation of the iron is already well under way when the aërator is reached, the subsequent removal through settling and filtration being very complete. Another beneficial and at the same time interesting result of this mingling is in the fact that we have repeatedly found the mixed raw water, as emerging at the aërator, to be practically sterile, showing from one to three bacteria only on agar, and from ten to twenty only on gelatine, as against two or three thousand on gelatine in the original pond water.

Under the terms of a law enacted in 1899, practically all of our surface supplies, including even the larger lakes, have gradually come under the sanitary protection of special regulations promulgated by the state board of health, following application therefor by the local water commissioners. These regulations, of the same general character as those adopted by a number of other states, are enforceable by the local boards of health and carry a penalty for each violation of twenty dollars.

Formerly it was quite the thing for our pond supplies to serve the cities and towns in a dual capacity, and unfortunately the practice is not yet altogether abandoned, although during the past ten years the idea has been fast going out of fashion. Thus the little lake or pond a few miles outside the city has not only furnished the drinking supply for its citizens, but there has been expected of it that it should serve as the local summer pleasure resort, as a trolley terminus picnic ground, a place for boating and fishing. It was no unusual sight to see the shores of the municipal drinking supply lined thickly with summer cottages, with regular lines of steamers or launches plying over the surface during

the season. But of late this sort of thing has been frowned upon; city fathers have regulated, and public sentiment has objected, to such a degree that the possession of such a summer place, in view of all the restrictions imposed and the prohibition against bathing, has become unpopular. Our more progressive cities have long ago adopted the policy of buying up these shore properties and re-foresting the watershed.

In this connection an interesting case has recently come up involving the supply of the city of Concord. This consists of a pond of about 340 acres. When the source was adopted, a dam was constructed upon the outlet brook so as to flow an additional thirty acres of land owned by the city. Eventually this second smaller pond thus created became a sort of harbor for the mooring of boats. Being near the trolley, a public picnic ground was established upon its shores, and here the owner of a line of pleasure steamers constructed his wharves and boathouses. It was always assumed that inasmuch as this was apparently a public body of water within the meaning of the statute, it would be impossible to deprive the public of its constitutional boating and fishing privileges thereon. Recently, following the gradual purchase and removal of practically all of what was once an extensive colony of summer cottages, the city proceeded to attack the boating problem. First, it declared that the smaller pond was not a part of the main lake, although connected therewith by a narrow channel; also that, notwithstanding its area, it was the private property of the city, in which the general public had no rights.

In accordance with this decree, the commissioners ordered the removal of all boats and wharves from the smaller pond. Second, boating and fishing in the main lake was likewise prohibited, subject to a proviso: that, following formal application from a responsible person, the superintendent of the water works might, in his discretion, issue a limited period permit to such person and his household to go upon the lake with the exception of that portion within one-quarter mile of the intake. Each such applicant is required to sign an agreement that he will comply with certain regulations, which are set forth in detail.

Following defiance of these rules by the owner of the steamboat line, the superintendent of the works proceeded to remove his

boats and to demolish his wharves. It is a matter of special interest to note that, in the suit which resulted, the city's contention has been unequivocally upheld by the Court, it being ruled by the latter that the orders issued were entirely reasonable and proper in the interest of protecting the purity of the public water supply. While such a decision might be anticipated, as being in keeping with the present trend in such matters, yet, as many of you will realize, the result might have been somewhat different a generation ago.

Of course such drastic control of navigation is hardly feasible in the cases of the larger inter-township lakes, yet the Concord action goes to show what can be accomplished in those numerous instances where a body of water, although of sufficient area to bring it within the designation of a public pond, is, nevertheless, hardly more than adequate in size for the reasonable storage needs of a public system.

In the instances where we find the colon bacillus in our public supplies, it is present in nearly all cases as a result of pasturage of the watershed, drainage from cultivated land, or wash from highways. In a case recently coming up where the intake was in a roadside stream a mile below the lake outlet, the contamination of this brook by roadwash was shown to be so extensive, particularly at certain seasons, that the water company has been compelled, following an order, to extend its main back up to the lake.

Most of our superintendents now appreciate the desirability of controlling at least enough of the watershed to exclude pasturage of a nature or extent liable to cause contamination. As an example of what may happen, an experience with the Antrim supply may be cited. We were called upon during the course of an exceptionally dry season to investigate a sudden wholesale appearance of dead tadpoles in the water. The pond in question, without inlet and mainly fed by surface wash from the abrupt and rather limited watershed, is but sixteen acres in area. At that time the shed was quite extensively pastured, with no fencing, cattle having access to the pond at every point. The pond level was far below the top of the outlet dam. At one end, and extending well into the pond, there was discovered a regular barnyard wallow, odorous and liberally manure-besprinkled, and evidently

representing the daily drinking and wading place of numerous cattle. Examination of the water showed a vile condition, an interesting feature being the increased chlorine content, more than ten times the normal. As a result, this system was out of commission for domestic use for thirty days.

At the present time there are eight filter plants in New Hampshire. Those at Exeter, Berlin, Lebanon, and West Lebanon are of the mechanical type, while Somersworth, Dover, and Franklin have the slow sand variety. The eighth, of special type for deferrization of the Merrimack supply, has already been referred to. The principal function of the Dover filter, which is a standard, covered, two-bed construction, is also that of iron removal. The West Lebanon filter is for the removal of color from a reserve storage, and those at Berlin and Franklin are also requisitioned only at times when the regular source is insufficient and the river has to be resorted to. Hypochlorite is employed with both the latter as an auxiliary treatment, while at Somersworth the filtered water is subjected to disinfection by chlorine gas.

The use of hypochlorite or chlorine is now practiced, either continuously or as needed, at six plants, these being Berlin, Franklin, Laconia, Somersworth, Raymond, and Woodsville. Brief reference to the Somersworth system will be of interest. The source is the Salmon Falls River, which receives the sewage of a number of towns, besides a certain amount of industrial refuse. The single-bed filter, constructed in 1897, and said to be the second covered plant to be built in this country, is of the design of the original Lawrence structure. The area is one-half acre, and, as the daily consumption ranges from 450 000 to 600 000 gal., this means a rather low filter rate of approximately one million gallons per acre per day. This fact and the comparatively high level of five to six feet of water upon the filter, together with a uniformity coefficient for the sand of approximately three, probably explains the unusual working capacity of this filter between cleanings, it never having been the practice to scrape the surface oftener than twice in any one year.

Because of the limited storage, sufficient for no more than two days, filter-cleaning has always been a somewhat difficult proposition. The practice has been to get the standpipe full, then put on a large gang of men and push the job as rapidly as

possible. Obviously, the efficiency of the filter immediately following cleaning is extremely low, and, as an agency to be relied upon for the uniform and continuous purification of the comparatively bad raw water, it has proved somewhat of a delusion.

Early in 1913 a chlorine equipment was added to the system, this, again, being the second installation in this country to regularly employ chlorine gas in conjunction with a municipal water system. This treatment, which involves the use of three to four tenths parts of chlorine per million, has proved thoroughly successful. Instead of being a mere auxiliary to sand filtration, it is in this case — at least during certain periods — actually the mainstay of the purification treatment.

For a filtered water, that of the Somersworth system is relatively rather highly colored, running some forty to fifty parts per million. Already possessing the most expensive item of a color removal equipment, i. e., the filter, it must immediately occur to any engineer that the city is acting unwisely in failing to complete and get the full advantage of this equipment through the installation of means for applying coagulation.

The first plant in the state to use hypochlorite was that of the Laconia Water Works, this treatment being installed in 1912. The source is Lake Paugus, an arm of Winnepesaukee. Although chemically and physically this water is always of unusual excellence for a surface source, yet bacterially the results of examination were not always satisfactory, and because of certain unfavorable conditions, the adoption of a disinfection treatment was recommended by our department

A rather remarkable feature in connection with the Lakeport chlorination is the extremely small dosage required, due to the unusual natural purity of the source. Although it was originally planned to use from .20 to .25 parts of chlorine per million, it has been repeatedly demonstrated that as little as one tenth part, corresponding to as little as two and one-half pounds of bleach per million gallons, is ordinarily ample for the removal of all bacteria of intestinal origin and for 99 per cent. or more of the total bacterial count.

The Lakeport plant and the results achieved there in water sterilization form an excellent illustration of what can be done and should be done in the cases of very many of our New England

surface waters in order to place them upon a higher plane of safety. Very frequently there is no occasion for resorting to expensive filtration. Chlorination, preferably through the medium of chlorine gas, solves the problem. The writer has felt for some time that, as a final precaution,—as a comparatively inexpensive variety of insurance,—the application of a treatment of this character would be an excellent thing in the case of almost any of our surface supplies.

Since 1913 New Hampshire has had a law which provides in effect that before any new source of supply may be adopted, or any extensions or additions made of existent sources, an examination of such source by the state board of health shall be made, full plans submitted, and the approval of the state board secured. In our estimation, this is proving to be a very wise and beneficial law. During the last session this law was amended so as to give the state board of health special control of emergency intakes drawing from unapproved sources, also of industrial connections in the case of manufacturing plants having a secondary system of supply for fire protection. A feature of the law is that the existence of all such intakes and connections must be placed on record with the board. Already we have discovered a number of bad cases, where a highly polluted factory source was separated, in an emergency, from the regular public system merely by a single antiquated check-valve. In such cases we have required the installation of the Factory Mutual type of connection, involving two check-valves of special type placed in series. At the present time, at least, we are disposed to believe that, while such a connection does not afford the consumer absolutely perfect protection, yet it represents a decided improvement over the older type of connection and one that is apparently tolerably safe in most situations.

From the standpoint of health protection, our department has always felt considerable interest in the service pipe problem. It has become a fixed policy with the New Hampshire board to advise against the use of lead as a water-conducting medium in the case of private supplies, and it is probable that under the law cited, any further proposed installations of public character involving the use of lead pipe would not receive the sanction of the board. During the past fifteen years, as a result of numerous cases of lead-

poisoning arising, hundreds of these lead-conducted systems have been condemned.

Contrary to the common notion, the incrustation which forms in lead pipe is not an innocent coating of lime salts, but instead is a carbonate of lead, quite insoluble, it is true, in carbon dioxide-free water, yet very readily soluble as a highly poisonous compound in water carrying this gas in appreciable amount. For this reason we have found the amount of dissolved lead liable to considerable fluctuation, and that the results of analysis at any one time cannot be accepted as an altogether reliable criterion of what may be true at other times. Because of the fact that surface waters, containing as they do but slight amounts of carbon dioxide, have very little action, as a rule, upon lead; because of the difference in individual susceptibility; and because of the frequent extremely slow and insidious progress of lead-poisoning, practical water-works men are, it would appear, inclined to adopt a more or less skeptical attitude toward this question,— an attitude which is not justified by our actual knowledge of the subject.

Probably 90 per cent. of the replacements in the case of private systems are with galvanized iron. We have found that with ground waters carrying appreciable amounts of carbon dioxide there is a tendency to considerable solution of zinc, such amounts as 3, 4, and 5 parts per million being not unusual, while much more even is at times encountered. Although unfortunately there is very little clinical evidence as to the toxicity of minute amounts of zinc, yet there would seem to be no room for question that the daily ingestion of the amounts referred to must be, to say the least, objectionable. For that matter, there are certainly grounds for believing that even such a supposedly innocent and beneficial substance as iron is deleterious as a daily diet year in and year out, when the quantity of this metal present in the water is sufficient, as is sometimes the case, to impart a faint but noticeably astringent taste.

"What kind of pipe ought we to use?" has become a rather familiar inquiry. In view of the fact that the merits of cement-lined iron have for a long time appealed to the writer, he is especially interested to note the sentiment manifested in its favor at this time.

FORESTRY IN RELATION TO PUBLIC WATER SUPPLIES.

BY PROF. J. W. TOUMEY, DIRECTOR SCHOOL OF FORESTRY, YALE UNIVERSITY, NEW HAVEN, CONN.

[*Read February 14, 1917.*]

I was very glad when your President sent me a letter, several days ago, asking me if I would address this body of men on the subject of forestry in its relation to the potable water supplies of New England. I wrote him that I would be pleased to do so, because there is no body of men that can undertake the practice of forestry with the reasonable expectation of economic success better than the men who control the drainage areas from which the potable water supplies of New England come.

Introductory to what I am going to say this afternoon, I would like to call your attention to what the forest condition was in New England at the time of the settlement of the country, and why it has come down to us in the condition that it is to-day.

When New England was first settled, the entire area was covered with virgin forest, with the exception of a few scattered places here and there where the Indians grew their corn and tobacco. The settlers who came into New England first cleared the woods from the valleys and the richer portions of the land. As settlement increased, they extended their clearings over the hills and the low mountain sides until they extended far beyond the area of what is strictly agricultural land; and seventy-five years ago there was more land in cultivation in southern New England than there is to-day.

It was necessary, it was sound economics, it was wise, to clear the land in the process of settlement, so far as it could be used for the production of agricultural products. But the work of utilizing the forest extended far beyond that. It went so far as to extend over large areas which were not agricultural. By repeated cuttings, by repeated burnings, the productive power of these non-agricultural lands was reduced, until to-day in many parts of New

England the more of this exhausted land a man owns, the poorer he is. There isn't any question in my mind but that the greatest economic problem that is before this country to-day, with our rapid increase in population, is the use of land.

Land is strictly of two kinds, and it serves three fundamental purposes, namely, to feed, clothe, and shelter man. Land is agricultural or it is forest land; it produces agricultural crops and it produces forest crops.

In October, 1913, the *Yale Review* published "Earth Hunger," the noteworthy essay by W. G. Sumner, the celebrated American economist. Professor Sumner states in this essay that earth hunger is becoming the wildest craving of modern nations. "They will shed their life blood to appease it. It gratifies national vanity and economic expansion both at once. No reasoning can arrest it and no arguments satisfy it." The truth of this statement by Sumner, published in 1913, is now being verified by the greatest spilling of human blood that the world has yet seen. The business of life as time goes on must center in getting more subsistence out of each acre of land, because this is the only way that each nation can support more people or support the same people as at present in a higher degree of comfort. How to get the maximum of the materials that feed, clothe, and shelter mankind out of the land is becoming essential with the passage of time. Increased production of materials from the land will, in the future, measure the capacity and power of the different nations.

With this brief introduction I want to call your attention directly to what you who have to deal with the potable water supply of New England can do and what you ought to do. You are accumulating, probably faster than many of you realize, when you take the whole of New England into consideration, vast areas of land. To-day every potable water supply company, every corporation which has to do with providing water for the public to drink, is concerned with the source of that water. You want to have pure water. That means that you have to control to a greater or less extent large bodies of land that surround your reservoirs. Some single cities already in the East own as much as twenty-five thousand acres of land; many own five thousand, eight thousand, and ten thousand acres. There are a great many cities and towns

in New England, and in the aggregate they own a very large amount of land.

Furthermore, this land for the most part is accessible to large communities that have need for wood. If you are going to accumulate large bodies of land of this character, it is absolutely necessary, in the economic development of the country, that you put that land to its best use consistent with a pure water supply. How can you use it? There is only one use that it can serve, and that is to grow timber. You cannot farm it, you cannot have people living upon it, you cannot have the source of the water supply contaminated. You must use it to grow timber.

This fact is already recognized by a great many people in New England. But there are men who say, "Is this a profitable undertaking? Isn't it pretty small potatoes for a water company to undertake the growing of timber?" I would say to you that if it were not necessary for you to own land, or from the fact of ownership put that land to its best economic use, it would be an unwise thing for you to purchase land to grow timber or to grow anything else. But so long as you must have the land, and so long as the area owned by you is very rapidly increasing, it must be put to an economic use or some day the public won't stand for it.

I could take you to scores of places I have visited abroad that illustrate in a very clear manner what this problem of forestry in connection with potable water supply means. The city of Vienna, with over a million and a half population, derives its water from a low rolling area of limestone hills, stretching almost from the gates of Vienna to the Austrian Alps. That area is covered with timber. The net annual return to the city from that forest is about six dollars net per acre. Those of you who have 10 000 acres of land in your watershed would be interested if you could get an annual revenue of $60 000 out of that item alone. You can't do it now, but some day you can. The small village of Forbach in Baden, in the Black Forest, derives a net annual revenue of $12 an acre from its forest, and has for a number of years, and will continue to do so for an indefinite period to come.

If that is possible in the settled communities of Europe, with our rapid increase in population it is just as sure that it is going

to be possible in this country. There is no question about it. It is in the future, however. But a corporation ought to look into the future and not be concerned solely with the things of to-day.

I presume that many of you gentlemen who have control of land look upon the possession of it as a necessary evil because you are not getting anything from it and, moreover, you can't see how you are going to get very much from it in the future. You haven't any trees on those areas that are worth anything, speaking in a comparative way, and that is the reason you aren't getting economic returns from them. You aren't going to get anything worth while if you are going to grow, or let grow by themselves, nothing but scrubby hardwoods. You can take to-day, or a forester can take to-day, any of those areas of mixed hardwood scrub and by the closest calculations that interest rates allow, he cannot figure out any profit in the long run, or but very little. The growth is too slow and there is too large a percentage of it which is unmerchantable. The thing is to convert those areas of hardwood culls into profitable stands of timber. You can't do this in one year, or in ten years, but you can do it in a hundred years. You should begin now.

New Haven County, one of the earliest settled counties in this country, — settled nearly three hundred years ago, — has to-day forty-six per cent. of the area of the county in wood. It has twenty per cent. more wood than it had seventy-five years ago. A careful survey was made six or seven years ago to ascertain what the owners were obtaining from these mixed stands of miscellaneous hardwoods, — uncared for and frequently burned, and aggregating about 85 000 acres, — and the average gross returns were between 50 cents and $1 an acre. You can readily see that these results indicate that there is not very much ahead in that kind of growth. You know very well that a savage will require one hundred acres of wilderness to obtain as much of the essentials of life as a civilized man will obtain from an acre of cultivated land. Wild woods require ten times the acreage to produce as much useful material as an acre of managed and cultivated woods, in the sense understood by a forester.

Now, if this is true, what are you going to do? You begin

to-day, to-morrow, next year, ten years from now, or at some time, to handle your land in a productive way; and I believe the sooner that you, who have charge of the watersheds from which the potable water of New England flows, get the point of view of improving the watershed from the standpoint of productive timber, the wiser you will be. You may not be in a position to do very much the first year. Forestry is a long-time proposition. It doesn't matter so much whether you begin this year, or whether you begin next year or the year after, or how much you do this year or how much you do next year, as it does to get the point of view of the direction in which you are going.

To point out in a general way what you can do, I call your attention to one water company that I am fairly well familiar with, that is, the New Haven Water Company. Fifteen years ago a portion of the area owned by this company, which owns between nine and ten thousand acres, was placed under management. Later, under the direction of the Yale School of Forestry, the remainder was placed under management. The company now has a forestry department which is concerned with the growing of timber and the taking care of timber, and nothing else. The work started by having a careful preliminary report made of all the watersheds owned by the company. I believe that this is the first thing that any one or any water company who is going to undertake this forestry proposition has to do. The report must not be made by a boy; it must be simple, it must be clear-cut, it must be direct, it must show what you have in the way of timber and wood, and what the quality of the land is.

I haven't the preliminary report which was made to the New Haven Water Company, but I have here a few copies of a preliminary report made of a forest property that is owned by the Yale School of Forestry at Keene, N. H. This will show you something of what ought to be embraced in such a report, when made for a water company or for any other corporation or any other body of men that have big tracts of land that they want to put under management and want to handle from this long-range forestry point of view. If any of you will send me a letter, addressed to the Yale School of Forestry, New Haven, Conn., I will be very glad to send you one of these reports.

From the preliminary report and later studies, a working plan is made under which it is proposed that the property will be handled or managed. I have here the first working plan which was made for the New Haven Water Company, and I believe it is the first working plan published by a water company in this country. I would also be glad to send to you gentlemen copies of this working plan.

What has resulted from the work of the New Haven Water Company? The lands which they own are miscellaneous in character, poor farm lands for the most part, with patches of coppice timber here and there, and open meadows. I presume it is the same character of country that most of you have in your own watersheds. What are you doing with your land? The New Haven Water Company is doing three things:

First. Planting conifers on all open land — and there are thousand of acres of such land.

Second. The lumber on brush-covered areas is permitted to grow until it is large enough to cut for fuel, when it will be cut and the areas planted with conifers. Where areas are covered with scrub, we find that we can't plant satisfactorily, and the cost of clearing is prohibitive. If they are permitted to grow until the growth is big enough to cut for fuel, it will pay for the cost of clearing. After cutting, such areas are planted with conifers.

Third. The areas already in good hardwood timber and in stands of hardwood and hemlock are thinned periodically and kept in healthy condition. Improvement thinnings are made as early as the material cut will pay the cost of removal.

Observe in this working plan that everything is hedged in by the question of cost,—and it has to be so. The possibility of thinnings is determined by costs; cuttings are made when justified by market conditions.

All of the over-mature timber, all of the wolf trees, all of the large material which isn't improving, is cut as rapidly as practicable.

The hardwoods at the tops of ridges and wherever else the forest serves its greatest protective purpose are maintained in the uneven-age form. I mean by this that the land is not cut clear. The mature trees are taken out a few at a time.

What is the long-vision point of view in this work? The aim is, by handling the property under modern forestry methods, to bring every acre to its highest productivity; that is, to bring each acre into a condition under which it will produce the most material and produce material of a quality which will fetch the highest price. We don't want fuel wood; we want something better than fuel wood.

You can readily imagine that a company starting with old stands of wood which have been burned here and there, woods that have been neglected for a hundred or two hundred years, will find it a tremendous job to change from the method under which they have been going downhill to a method which looks upward and which will ultimately result in developing a satisfactory forest.

The New Haven Water Company in the last nine years, since accurate data have been kept, has sold about $37 000 worth of wood products. What has it done with the money? All of its forestry work, all of its forest improvements, all of its forest help, has been paid for out of it, and there is to-day credited to the Forestry Account some eight or nine thousand dollars. The forest has been turned from the condition in which it formerly was into the new order of progressive development. Over $13 000 have been spent in planting alone, and it is the fixed policy of this company to plant approximately 250 000 trees a year. The planting is done at a cost of about $11 an acre. The first plantations made fifteen years ago are so large one can well get lost in them. The planting has been uniformly successful.

If you gentlemen are going to spend money in improving your watersheds from the standpoint of forestry, you must have a reasonable assurance of getting something out of them in the future. The trees which are always going to fetch the best prices when grown in large numbers are soft woods. This is so in Europe. To-day in Europe, after centuries of forest management, hardwood stands are continually decreasing and soft-wood stands increasing. I have never seen a hardwood stand in Europe which produced anything like the revenue per acre that stands of soft wood produce. A soft-wood forest may produce an annual net revenue of $12 an acre in some parts of Europe; this is never possible with a hardwood forest. You can figure out in New England but very little

profit from hardwood. The growth is slow and the amount of salable material is comparatively low.

Near the property of the School of Forestry at Keene, N. H., a Mr. Ellis two years ago sold the second-growth pine on twenty-two acres when sixty-three years old, — no better than what you should expect on equally good land if you planted pine 6 by 6 feet apart in New England, — for $15 000.

In 1871, also near to the property of the School of Forestry at Keene, an old gentleman one spring took a dishpan and gathered some white pine trees. He planted them eight feet apart in each direction on a precipitous slope near his home, on land worth less than $10 an acre. He died some three years ago and that property of less than three acres was sold for $1 000.

This isn't a fairy story; it is what we can expect. Some day timber is going to be worth more than it is to-day. Those who plant to-day are reasonably certain that they are going to get more for the timber when it is grown than the market will give them to-day for the same class of timber. The trend in the long run is going to be uphill for timber values, although it is going to be fairly slight until our large surplus supply of virgin timber is exhausted.

I want to say to you, I want to leave these words with you, if you are thinking of practicing forestry on the properties that you have in charge, — take it up in a serious way. I believe that a water company should consider forest esthetics as secondary to timber production. If you get a good productive forest, it is just as beautiful a forest as you can have. Every forest that is owned by a municipal water company abroad is handled from the standpoint of the economic production of wood. Those forests are traversed by thousands of people every year. In the beautiful *Wienerwald* near Vienna, there is easy and rapid transportation by train and automobile, and there are inns to accommodate the people who go there for recreational purposes, yet the city is getting very large annual returns from the timber. The forests are handled from the standpoint of timber production, from the standpoint of making the land productive.

Those of you who have not undertaken as yet the handling of your forest property from the standpoint of timber production

should first make a careful examination of your property. Have it made by some one competent to make it and give you the information necessary to show you what the possibilities are. This report on the Keene forest is suggestive of what a report ought to show.

After the preliminary report has been made by an experienced and competent forester, there should be a man in your company's organization directly responsible for the forestry work. He should give all or a part of his time to the carrying out of the work planned by the forester; and, if the property is large enough so that the receipts will justify it, you should have permanently at your command the services of a consulting forester, just as the New Haven Water Company has to-day, who looks into the future, knits the various projects together, and points out in his working plan how much is to be done each year, and how the material is to be disposed of. The cutting of timber, the selling of timber, the planting of trees, and the wise handling of a forest property require special knowledge. You can't leave these to any one whom you chance to employ.

You should have an inventory of your property. I mean by this that a map or maps should be prepared upon which are located the areas of woodland. The maps should be on a reasonably large scale, on which the woods are classified by types and stands, and where there is a record of the amount of wood of various classes in each unit.

On the basis of the maps and on the basis of the figures that have been obtained in the inventory of the property, the forester is able to draw up a definite working plan. This definite working plan should be adhered to so far as possible until it is revised.

Discussion.

John Kelso, Esq.* From time to time the water rates in Providence have been reduced when the earnings were in excess of the amount required to take care of the principal and interest on the bonds issued up to that time on the plant. Finally, the Council decided that it would set aside this particular surplus towards

* Of the Water Supply Commission, Providence, R. I.

a depreciation and extension fund instead of reducing the rates, having in mind that it would be well to have such a fund in order to buy up odd pieces of land that might be obtained. This action was very gratifying to the Committee on Increased Water Supply, as it gave them quite a sum of money for its preliminary investigations, without exciting unduly those of our citizens who would be inclined to profit by speculating in properties which it was necessary for the Board to secure to construct our new reservoir. The resolution of the City Council is as follows:

"Sec. 60. A special fund to be known as 'Water Works Depreciation and Extension Fund' is hereby established for the following purposes. The city auditor, annually, on the last business day of each fiscal year, shall determine what amount of money is equal to three per centum of the valuation of the water works, as shown by the city auditor's annual report for the last preceding year, after deducting from said valuation the value of the land owned by the city and included in the water works, and shall forthwith cause such amount of money to be paid to the board of commissioners of sinking funds and charged to 'water rents.' Said board shall hold said fund and all payments therefor and earnings thereof as a separate fund of the city, with full power to control, manage, invest and reinvest the same, and said board shall pay to the city treasurer such portions of said fund as the city council shall from time to time direct. Said fund shall be used and expended under the direction of the commissioner of public works, only as ordered by the city council, for replacing buildings, or machinery included in the water works which may become unserviceable, for any expense of extending the water works system, for the purpose of increasing or improving the source of supply, and for replacing such other unserviceable property included in the water works as said city council may direct."

I would like to ask Professor Toumey whether he thinks it would be better to spend the money in buying parcels of land or in planting trees.

Professor Toumey. I should say that, in most instances where the amount of money available for the improvement of the watershed is small, it is a better policy to expend it in the purchase of parcels of land instead of planting trees. It is the best policy to acquire a reasonable amount of land first. The improvement of the forest can be begun later. The watershed should be

developed as a forest and not as a park. Personally, I am sorry that the term "outlying city park" ever came into use in this country. In my judgment, there isn't any such thing; it is an outlying forest. Who wants to go into the country to see an open park? An open park is well enough in the city, but when we go into the country, take our lunch basket and go for a day, we want to go into the wild woods. The woodland protecting potable water should not be called a park; it is a forest, — and it ought to be a forest, because a forest can best serve for the kind of recreation that is needed by the public and, furthermore, it can be made a source of revenue.

The main thing to consider in developing the woodland owned in connection with potable water supply is the right kind of a start. Have the right point of view in beginning the work tending toward the development of the forest. If we start with the right point of view, we are justified in planting and in other development work as rapidly as funds are available. We should begin right. A large property demands a well-worked-out preliminary report in order to know what we have. As the work progresses, a working plan should be made for the property.

President Saville. Among the many far-sighted plans the carrying out of which has made the Metropolitan System a model, has been that in connection with forestry work on the Wachusett System.

Mr. Hiram A. Miller.* When we started on the Metropolitan work, we got somebody from Washington, whose name I do not now recollect, to go over the territory, some five thousand acres, and make out a preliminary report and something in the nature of a working plan, — although it was hardly definite enough to be considered a working plan. We took that up, and the first thing we did was to establish some pine-tree nurseries, and we have had three different nurseries at one time, although one of them was subsequently abandoned. Of course we made some mistakes, because we were rather green at the work twenty years ago, and there wasn't so much known about forestry in this country then as there is to-day.

In our first experiments we planted, alternately, hard maples

* Consulting Engineer, Boston, Mass.

and white pines. I think they were four feet apart, the idea being that we would cut off the maples after they got large enough for cord wood, which was the advice we received at that time. Then we thinned over quite a lot of the tract and divided it up into parcels of thirty to sixty acres as the topography of the tract would permit, by roads, so that we would have a sort of a fire guard, and also access to all of the land, so that we could get around each one of the tracts by these roads, which were decently passable, fairly good woods roads. On the outside tracts, where we came in contact with land which the Metropolitan Board did not own, we cleared a fire guard one hundred feet wide. The thinning hadn't been carried to a very great extent when I left. Some of the tracts were improved in that way, leaving the better timber growing, with very little of what could be called mature forest on the tract, because as soon as it got so that the farmers could sell the wood for a small sum they always sold it, so that there was very little on the whole tract which was of any value except for cord wood, and, of course, a very large proportion of it was brush. We tried planting some in the brush, but we found, as Professor Toumey has said, that that didn't work well. We planted some areas and then would cut the brush around the pines as it grew up, and try to give the pine trees a chance to grow, but we didn't succeed very well. It cost too much. I left the work with Mr. Allardice when I came away.

Mr. E. R. B. Allardice.* During the past twenty years, the establishment of a forest cover over the lands bordering the Wachusett Reservoir of the Metropolitan Water Works of Massachusetts has been actively prosecuted with the fourfold end in view of —

First, preserving and increasing the purity of the water supply.

Second, conserving the run-off in the spring months.

Third, utilizing for commercial purposes what would otherwise become a wild and waste tract.

Fourth, establishing what has proven to be a sanctuary where numerous wild animals and birds enjoy the protection which such a reservation provides, and where they can, with a certain degree of safety, propagate.

* Superintendent Wachusett Department, Metropolitan Water Works, Mass.

The watershed area tributary to this reservoir covers about 118 square miles, of which about 7 square miles — bordering on the immediate shore of the reservoir and extending along the principal tributary streams — are owned by the Commonwealth and controlled by the Metropolitan Water and Sewerage Board. This area of about 7 square miles has been developed along the lines of modern forestry from a pre-arranged plan whereby the land could be put to its most economic use without affecting, to the slightest degree, the paramount purpose of securing a pure water supply. Those portions of the reservation, consisting of arable, pasture, and light sprout land, have been planted to native white pines, making a self-perpetuating forest which would ultimately provide a complete ground cover, requiring no artificial fertilizing or disturbing of the soil, and which would protect the waters of the basin from the direct contamination of manurial matters and soil washed from adjacent farms during heavy freshets of spring floods. The white pine was selected because of its almost universal adaptability to the various kinds of land and growth to be treated, its freedom from leaves, its rising value in the lumber market, and the ease, low cost, and its then comparative certainty of raising to maturity.

Thus far, some 1 425 acres have been planted with coniferous trees — mostly native white pine — using some million and three-fourth seedlings, the greater proportion of which have been raised in nurseries established and maintained for this purpose, though of late about one half of the seedlings set out have been furnished by the State Forestry Department. The reservation includes some 1 690 acres grown to deciduous trees of many varieties, — mostly chestnut, oak, and maple, — which are from time to time being thinned and improved to increase their ultimate commercial value.

In addition to these two general divisions of the reservation, there are 870 acres on the back slopes of the dikes, and numerous vistas which are preserved as grass land and which it is planned not to forest.

There remain to be planted about 585 acres of land, the seedlings for which are being raised in our nurseries.

Because of the damage done to the white pine by the pine-tree

weevil, and the threatening danger from the blister rust, our present plans include the use of the red pine on about a fifty per cent. base, they being (as far as is known) immune from both of these destructive elements.

The benefits to be derived from the presence of these large pine stands — where the flood run-off in the spring is materially lessened and the melting of the snow, continued to late in the season — are apparent even now, where the trees are from fifteen to eighteen years old.

For further protecting the waters of the reservoir, a continuous compact screen of arbor vitae has been set out along thirty-two miles of the shore, to prevent foliage from being blown into the water. Two rows of trees two feet apart, with trees three feet apart in rows, were set out, and to-day there are long stretches where they are from eight to twelve feet high, forming a solid bank against which the dead foliage from the hard woods is blown. This screen has not, however, grown up uniformly, for, on the exposed location, along the southerly shore, the wind and ice storms have seriously hindered their growth, if not completely killed them.

The lower three miles of the Wachusett Aqueduct is of the open-channel type, with marginal strips of land varying in width from fifty to five hundred feet, which have, of late years, been planted to native white pine. At some places, where the marginal lands are low and swampy and not adapted to the white pine, it is proposed to set out American tamarack trees.

When the policy of making forestry work a part of a water-works system is adopted, numerous additional obligations are automatically accepted. For instance, the protection of the forests from destruction by fire and the ravages of the seemingly never-ending plagues which are sources of considerable expense. It is our policy to patrol the reservation on Sundays and holidays through the dangerous seasons of the year. The patrolmen carry shovels and fire extinguishers, while a forty-horse-power motor-driven power sprayer and pump is kept in readiness. Several gratifying experiences have proved the value of this machine as a fire fighter. Then, again, to properly protect the forests from the ravages of the numerous destructive elements which have

been handed us during the past few years requires the expenditure of considerable money if the full benefits from these forestry operations are to be realized. Our forestry operations are carried on by the regular water-works maintenance forces, augmented from time to time during the planting seasons.

The major portion of the watershed area is not owned or in any way controlled by the board, so as to be available for forestry operations, but there is evidenced on the part of a few of the more aggressive farmers a desire to follow our example in utilizing their waste lands. Undoubtedly this practice will increase from time to time, especially when we begin to get some financial returns from the investment. As this work on the part of the farmer is extended, the benefits derived from our operations should be much greater and the conservation of the run-off and quality of the water increased in the same proportion.

President Saville. Mr. Allardice, if you were going to start over again in forestry work, would you put in your own nurseries or buy your stock?

Mr. Allardice. I am very thoroughly convinced, from the success that we have had with our nurseries, that we have been wise in maintaining our own. At the present time we have two large nurseries with about 400 000 pine trees, half of which will be planted the coming spring.

Professor Toumey. What does your stock cost you?

Mr. Allardice. From published figures* of a 30-acre lot, planted 6 by 6, using in the neighborhood of 36 000 trees, our stock cost us $205. Those trees, as a rule, are three years old.

Mr. William F. Sullivan.† Professor Toumey likened his talk to a vision. I belive it was sound advice, common sense. Forestry bears an especially close relationship to water works, for do not most water works have some land suitable for forestry? Then why not develop it, and eventually get a crop, the kind of a crop that is feasible from this kind of property?

The professor also spoke of the low price of oak and scrub hard woods. I agree with him that the money received for this kind of cord wood has in the past barely paid for the cost of producing

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* Journal N. E. W. W. A., XXX, 83.

† Engineer and Superintendent Pennichuck Water Works, Nashua, N. H.

and delivering. With the high price of coal and the difficulty in obtaining it, I think to-day is a good time for owners of scrub oak and inferior species of hard wood to cut it out and sell it for fuel, also for water works to profit by the use of it for pumping fuel in place of coal. So, I say, cut it out now and get the advantage of the present fuel situation.

Occasionally there were men, years ago, connected with water works who had long vision. These men procured land around their water supplies. This was before scientific forestry attracted the attention of woodlot owners. These men purchased barren lands, scrub woodlots and sometimes timbered land. This land was gradually worked, so that to-day around many water supplies there are stands of merchantable timber. When these men first took up forestry, it was before much thought was given to the conservation of natural resources, or much attention paid to the pollution of streams. They did the reasonable and, in the light of present-day practice, the sensible thing, — they developed their woodlands. And to-day there may be realized in some places as much per acre as the professor stated was realized on those timber tracts near Keene, N. H.

Is it not a splendid thing for any community to have its water works develop and reforest the lands under its control, so that in time there will be public or semi-public forests for the public use and for recreation purposes under proper regulation? These reservations, either in parts or in the aggregate, will add to the beauty, the grandeur, and to the wealth of the state.

I agree with the professor that the so-called outlying or suburban parks do not seem to entirely satisfy the desire of the public for recreation purposes, for it is well-kept forests and woodlands which thrill one as he wanders and roams at will in the great out-of-doors.

Large water works like the Metropolitan, of Massachusetts, which has been spoken of here to-day by Mr. Allardice, nowadays have an expert and scientific organization. In addition, this organization has a yearly appropriation for improvements and development work in forestry. The Metropolitan and other water works are doing good work. One has only to visualize the Metropolitan land areas of years ago and then look at the same

territory to-day. This work will surely pay, not only in dividends but in pleasure to the inhabitants. The work which is being done under the supervision of Mr. Allardice will be worth to the state in scenic values alone more than it costs.

In small water works, with few men and limited funds, it is an excellent and paying work to have on hand and to do. At spare times, put what men you have on hand in the woods under intelligent supervision. In the winter time it will enable you to have a crew on hand who are earning their keep.

At the present time our company is logging and sawing timber which is merchantable. This is possible with us to-day because of the foresight of the men of several generations ago. Speaking of pine nurseries, in many instances there is no need of nurseries. The older stands of pine, with their "seeders," furnish natural reproduction nurseries in which there are hundreds of thousands of saplings suitable for transplants. A water works may during slack periods — or even sometimes between jobs — send a few men into the woods and set out thousands of these small trees.

It is a distinct asset to a water supply to have surrounding its ponds, lakes, and streams beautiful green trees, summer and winter.

Discussing the moth pests, a few years ago we were all much disturbed about the brown-tail and gypsy moths. We, like others, endeavored to control them. Some of our neighbors showed an unwillingness to do their part. The result was that we gradually relaxed our vigilance, and to-day it seems as if these pests after reaching their height are on the wane, have reached sort of a normal level where natural agencies are holding them in check. The depredations of these pests have not been as destructive as it was first thought.

To-day there are not as many fires in the woods as formerly. The public has been educated and cautioned. Willful or careless individuals have been penalized for setting fires. Hunters and fishermen are coöperating with the authorities and with the owners of woodlands, in the prevention and detection of forest fires.

At the present time, a company is being formed, with headquarters at Berlin, N. H., for the purpose of insuring standing timber. There is to be a meeting in Boston, next month, of large and small

timber-lot owners, to complete the organization. Application for a charter for this Standing Timber Insurance Company has been made in the state of New Hampshire. I understand at the present time there are over thirty fire protective associations in the United States. These associations, with state and federal forestry departments, assisted by the towns, railroads, and the public generally, mean the elimination and prevention to a large extent of fire wastes in woodlands.

"A long pull and a steady pull" by the individual, the water works, the state, and nation, in improving, developing, reforesting, and protecting their properties, means greater timber growth which will in future years stabilize the yield and furnish wood for the demands. It is also the opinion of many that reforestation and care of woodlands will, when the forests are full grown, show a substantial return on the investment.

Mr. Patrick Gear.* We started in Holyoke, some fourteen years ago, I guess, with about 2 500 acres of land that was covered with a lot of dead wood, crooked limbs, and broken trees and underbrush, and we cleaned it up. Like Mr. Sullivan, we had nothing for our men to do in the winter, and we wanted to keep them, so we put them into the woods. They cut out all the broken trees which were there, and got the hardwood out of the way, and now we don't have as many fires as we used to have.

We planted five or ten thousand white pines every year. We had trouble with our trees, a few years ago, and I sent up to Amherst College and got a professor to come down. He went all over the trees, spent a couple of days, and he found some kind of disease, which I think he called weevil. He wrote out a prescription for me which I could make up out of soap and kerosene oil, to spray the trees with. I bought a spraying machine and put two men out spraying the trees. So as to be satisfied that he was all right and that the trees would come out right, I left one corner which I didn't spray at all, and they are all alike this year, all good and healthy. The white pine blister they talk a good deal about, we haven't found yet.

Professor Toumey. I don't want to be put in the same position as the man who gave you advice about spraying your trees;

* Superintendent of Water Works, Holyoke, Mass.

but what you have said demonstrates one thing to my mind which is interesting. Trees have always grown, and they are going to grow. They are not going to disappear from the face of the earth. The thing we want to do is to have confidence and go ahead and plant trees. I don't believe that the white pine blister rust is going to wipe out white pines. I don't know just what it will do yet — nobody knows. It may be serious, we can't tell, but I would not stop work. I would do this, however, if I were going to plant white pine this spring — I would plant red pine in alternate rows with it. Then, if in later thinnings we find the white pine all right, we can cut out the red pine and bring the white pine to maturity the same as if we had planted all white pine.

Mr. Frank Winsor.* I did not come prepared to discuss this subject, but will say a few words relative to reforestation of marginal areas around the Kensico reservoir which forms a part of the Catskill water supply system for New York City. This reservoir is about twenty-six miles north of the Grand Central Station, and has recently been filled, there being a marginal area of about 2 500 acres around it upon which extensive work in reforestation was carried on under my general direction from about 1910 to 1915, at which time the greater part of the work was nearing completion. The 2 500 acres was divided into arable, pasture, brush, and wood land, the latter with a considerable percentage of chestnut growth which became worthless on account of infection and was cleared under a contract, the City of New York paying $11 900 for the clearing. The area, cleared of chestnut growth, amounted to about 750 acres having considerable chestnut upon it and 270 acres with sparse growth, and the contractor was entitled to the salvage from his operations as well as to his contract price.

In the early part of the work, underplanting was done on some of the more sparsely wooded areas, but as a general rule it was finally concluded to be inadvisable and to generally limit the work on land having timber growth worthy of preservation to improvement clearing. The greatest trouble experienced, and the greatest that will probably be experienced in any locality, is from fire. As long as irresponsible people are permitted to roam at will

* Chief Engineer, Water Supply Board, Providence, R. I.

through such reservations, smoking pipes, cigarettes, etc., there does not appear to be any way to prevent fires, and in grass land which has been planted with small trees it is very difficult to prevent such fires from doing great damage. Cleared land is generally planted with about 1 200 trees to the acre, — that is, about 6 ft. by 6 ft. With three- or four-year-old transplants, there will be required from three to five years additional growth before the trees are sufficiently high to be seen above the grass in the summer. It is impracticable to cut the grass and avoid injury to the trees, and in the dry weather of the late summer and fall it becomes a tinder box, and if a fire starts in it — even with a force to fight it near at hand — it will generally burn over a considerable area before it can be extinguished, thus ruining in a few moments large areas which may represent several years of growth of the trees planted thereon. While the fire hazard will always remain, it undoubtedly diminishes considerably after the trees reach a size sufficient to choke out the undergrowth. There is great need of more rigorous laws regulating trespassing, hunting, smoking, etc., as a protection for such reservations against fire. The protection around Kensico reservoir was undoubtedly greater than has obtained in almost any other area where such work has been undertaken, as the Board of Water Supply had a police force around this reservoir in addition to a large force of men in the employ of the city and of contractors, notwithstanding which a number of fires occurred which destroyed the results of several years' work. The experience at Kensico might reasonably be expected to be repeated on any reservation within, say, twenty miles of any large city in New England. On the reservation of the Metropolitan Water Works around the Wachusett reservoir, I understand there have been several disastrous fires notwithstanding the greatest care and a most thorough organization to combat fires.

Fire is by no means the only enemy to reforestation, as almost every tree planted brings some kind of a pest with it, as, for instance, the weevil and blister rust. I have somewhat the same confidence that Professor Toumey has that trees will always grow, but it is most exasperating to plant white pine, for instance, and have it virtually ruined by the weevil before this pest can be

arrested. The trees which appear to be the most successful from the standpoint of rapid growth, although probably not from the standpoint of commercial value, are the Scotch and Austrian pines. While these may be looked upon somewhat as weeds in the conifer group, they grow very rapidly, and for reforestation, which is not primarily perhaps for revenue, they are in many ways preferable to the white pine. The red pines, while slower in growth, are apparently well adapted, as are the white pines, to planting in this locality.

The above discussion is based primarily upon reforestation with conifers, which appear to offer the best promise of satisfactory results in this section of the country. The problem of taking care of the growth which now exists is, however, a serious one. The chestnuts have already disappeared in some sections, and it seems to be a question whether they may not be doomed in New England.

In the reservation for the Scituate reservoir for the new water supply for the city of Providence, there is a marginal area of over 7 000 acres, the disposition of which has not yet been decided upon. A considerable percentage of the growth upon this area is chestnut, which does not generally appear to be badly infected, but the permanence of which from experience elsewhere — notably in Westchester County, New York, where during a period of between five and ten years it entirely disappeared — is very much in doubt. Purely as a commercial proposition, taking into consideration the danger from fire and the difficulty of insuring proper maintenance during a long term of years, there probably is not sufficient commercial justification on the part of the city for attempting the reforestation of these areas. Looking at it, however, from the standpoint which Professor Toumey has so ably presented, it would seem perhaps that in this instance some work of this kind might reasonably be expected, particularly from a municipality. It does not, however, appear to me as being wise to attempt such work until the large forces of the contractors engaged upon construction are through with their work, and until more stringent laws than are upon the statute books to-day are passed, to control access to these areas and to minimize danger from fire.

BREAKS IN WATER MAINS.

BY S. E. KILLAM, SUPERINTENDENT PIPE LINES AND RESERVOIRS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read September 14, 1916.*]

Breaks in water mains, their causes, and means of preventing same, is a subject which is growing in interest to water-works officials throughout the United States, especially officials responsible for the supplies to thickly populated districts. The fact that it is always unknown when one of these breaks will occur is acknowledged by all engineers and superintendents having responsible charge of the water supplies as the most trying part of the maintenance of the water-works system.

The purpose of this paper is to give an account of the breaks which have occurred in connection with the supply of water to Boston, Mass., and the surrounding towns, known as the Metropolitan Water District, since the works were put in operation, January 1, 1898.

The Metropolitan Water District was created by an act of the state legislature in 1895 and now includes the following cities and towns: Boston, Chelsea, Everett, Malden, Medford, Melrose, Newton, Quincy, Revere, Somerville, Arlington, Belmont, Lexington, Milton, Nahant, Stoneham, Swampscott, Watertown, and Winthrop, — in all ten cities and nine towns. All of these, with the exception of Swampscott, are within ten miles of the State House, and all, with the exception of the city of Newton, are supplied with water from the Metropolitan works.

The works are under a commission of three appointed by the governor, known as the Metropolitan Water and Sewerage Board. At present the board consists of Henry P. Walcott, M.D., chairman; Edward A. McLaughlin, and Thomas E. Dwyer, with William E. Foss, chief engineer of water works.

Under the general act of 1895 the board was required to take certain existing works from the city of Boston. Since that time,

other existing works have been taken from the city of Boston, and the town of Swampscott, until at the present time there are 23.67 miles of mains, varying in size from 10 in. to 48 in. in diameter, that were laid from 1848 to 1897. The remainder of the works of the distribution system, amounting to 98.57 miles, have been laid since 1896 under the direction of this board.

The area of the Metropolitan Water District is 174.8 sq. miles, and the population as supplied, July 1, 1916, is estimated as 1 190-220.

After careful consideration of the subject, cast-iron pipe was adopted as the material for the use of all supply mains, and its use has been continued since. It is not the writer's intention to enter into a discussion of the merits or demerits of cast iron and steel as the material to be used for supply mains, but in passing desires to quote from the late Dexter Brackett's statement made before this Association on January 11, 1899, relative to the reason for adopting cast-iron pipe for the Metropolitan system.*

"During the past few years, pipes made from steel plates from one quarter to three eighths of an inch in thickness have, as you all know, been used to a considerable extent for mains of large size, instances of which will be brought to your attention this afternoon. The advisability of using this class of pipe for our work was carefully considered, as many of our mains were to be of large size. The thinness of the metal in the steel pipes renders the length of life of the pipe very much dependent upon the ability of the coating to prevent corrosion of the iron, and where pipes are to be laid in public streets, as ours were to be, and the coating constantly exposed to injury on account of public work of various kinds, I do not think it would be possible to protect the coating from damage, except at a very great cost. If the coating is not thoroughly protected from injury, there is, to my mind, a serious doubt as to whether it is advisable to use so thin a material.

"As you know, Boston and vicinity is not noted for the regularity of street lines, and the frequent angles required in the pipe lines to conform to the changes in direction, both horizontal and vertical, many of which, due to underground objects, were only discovered when the trenches were opened, would have delayed the work and increased its cost. It would also have been impracticable to have left the pipes exposed in the streets for any considerable distance in order to apply a water-pressure test,

* Journal N. E. W. W. A., *13*, 325.

which is absolutely necessary for riveted pipes. For this, and perhaps some minor reasons, it was decided to use cast iron as a material for our pipe."

Water is distributed to the several cities and towns through 122.22 miles of pipes from 60 in. to 10 in. in diameter. Connected with these mains there are 516 valves for controlling the flow of the water, and 59 Venturi meters of sizes varying from 6 in. to 48 in., by means of which a continuous record is kept of the quantity of water used in each of the eighteen municipalities supplied with water.

With the exception of a 30-in. wrought-iron, cement-lined pipe line, 11 200 ft. long, a 10-in. calomine pipe line 3 140 ft. long, and a few short lengths of steel pipe, all the distributing pipes belonging to the Metropolitan Works are made of cast iron.

The distribution system in the several cities and towns which are supplied with water from the Metropolitan Works contain 1 732.85 miles of pipe, 176 236 services, and 16 928 fire hydrants.

Every precaution was taken in the construction of the works to see that the pipes were properly inspected as to quality of material, workmanship, and coating at the foundry. The pipes were again inspected as they were delivered at the various pipe yards for imperfections and cracks. The pipe lines were laid under the direction of engineers and inspectors especially qualified for this work. Instructions were given to see that the trench was properly excavated, especially in a rock cut, where there is great danger of breaks occurring if all projecting points of the rock are not removed to a sufficient depth to allow a slight settlement of the pipe after it has been laid. The table on the following page is a list of breaks which have occurred on the Metropolitan Works.

Of the twenty-five breaks that have occurred on the Metropolitan Water Works system since January 1, 1898, seven have been on pipes of existing works that were taken as part of the system. Thirteen of these breaks were due to settlement of the pipe on to a rigid support which supported the pipe at only one point. Five breaks were due to cracked pipe, two to blasting, one to a water hammer caused by a pressure regulator, one to a spud of a dredge being dropped on to the pipe, one to a dredge pulling a pipe apart, one to a blow-out in a cement line, and one, cause unknown.

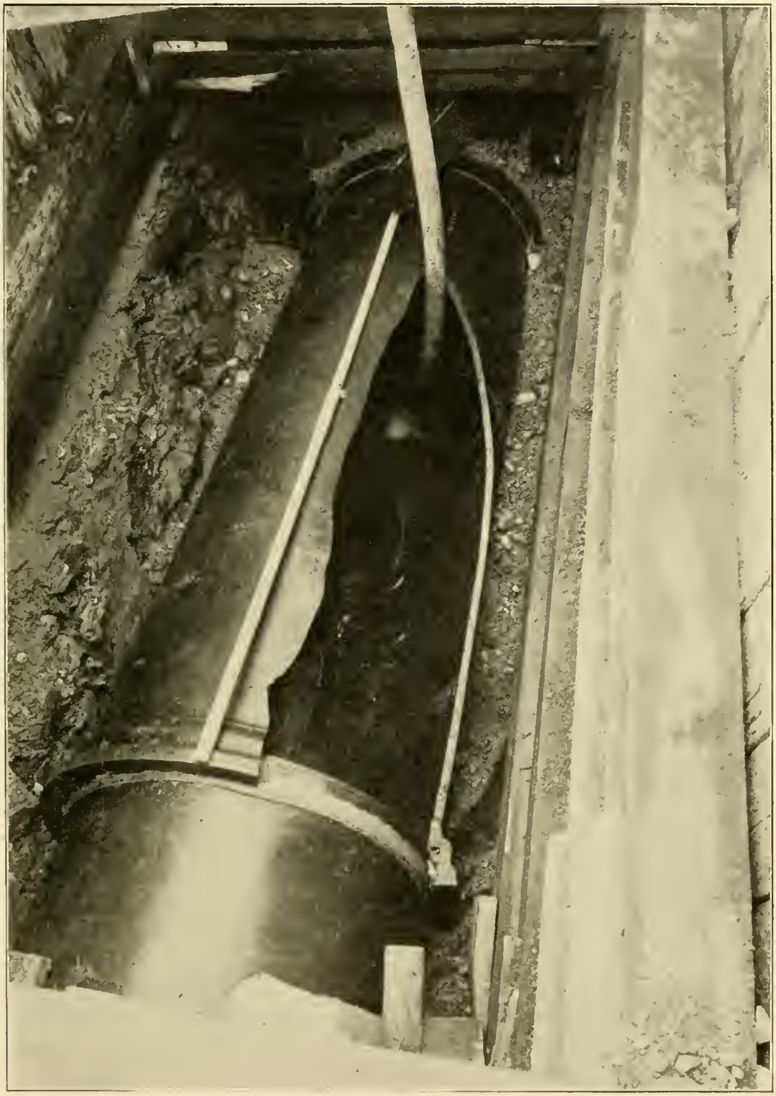
Date of Break.	Diam. of Pipe. Inches.	Location.	Reported Cause of Break.
Nov. 14, 1899.	36	Middlesex Fells Parkway, Malden.	Settlement on a bowlder.
Mar. 30, 1900.	20	High St., Everett.	Water hammer from pressure regulator.
Oct. 1, 1900.	48	Boylston St., Brookline.	Blasting.
Sept. 20, 1901.	24	Heath St., Somerville.	Settlement on ledge.
Nov. 29, 1901.	24	Main St., Somerville.	Cracked pipe.
Aug. 21, 1902.	30	Main St., Malden.	Settlement on ledge.
Feb. 25, 1904.	30	Chestnut Hill, Brighton.	Settlement on end of timber.
Oct. 16, 1904.	16	Winthrop Ave., Revere.	Cracked pipe.
Oct. 28, 1905.	36	Chestnut Hill, Brighton.	Settlement on end of timber.
Feb. 11, 1906.	6	Chestnut Hill, Brighton.	Cracked pipe.
Apr. 18, 1906.	48	Chestnut Hill, Brighton.	Settlement on aqueduct.
Nov. 1, 1906.	48	Washington St., Melrose.	Blasting.
Feb. 5, 1908.	36	Morton St., West Roxbury.	Settlement on a bowlder.
June 13, 1908.	24	Broadway, Somerville.	Settlement on ledge.
May 25, 1909.	48	Franklin St., Allston.	Cracked pipe.
Dec. 24, 1909.	48	Harvard Sq., Cambridge.	Settlement on electric conduit.
Feb. 13, 1912.	24	Adams St., Milton.	Settlement on sewer.
July 19, 1913.	24	Broadway, Chelsea.	Cracked pipe due to electrolysis.
Nov. 18, 1913.	24	Temple St., Somerville.	Settlement on ledge.
Dec. 4, 1913.	48	Clinton Road, Brookline.	Unknown.
Oct. 13, 1914.	36	Mystic River, Medford.	Spud from dredge.
Aug. 16, 1915.	12	Neponset River, Hyde Park.	Flexible joint pulled apart.
Nov. 6, 1915.	48	Commonwealth Avenue, Newton.	Settlement on ledge.
Nov. 8, 1915.	6	Mystic Station, Somerville.	Cement pipe, side blew out.
Apr. 23, 1916.	16	Fox Hill Bridge, Lynn.	Settlement on abutment.

The above table shows that thirteen of the breaks have been probably due to a slight settlement of the cast-iron pipe on to something solid, which emphasizes the fact that it is necessary to see that the rock is excavated to a sufficient depth to allow a slight settlement of the pipe after it has been laid. It also emphasizes the fact that great care must be taken in maintaining a line to prevent other structures being erected under the main so that there will be sufficient clearance to allow a slight settlement.

The writer has always found public service corporations willing to use due care when the situation was fully explained to them, but has always insisted that all work, where any structure was to pass under the Metropolitan mains, should be inspected while the work was in progress.

The following is a brief description of the most important breaks that have occurred on the Metropolitan Works as listed in the above table. The most costly of the above breaks occurred in Harvard Square, Cambridge, December 24, 1909, about 9.30 P.M., when the supply main between Chestnut Hill and Spot Pond burst, allowing a large quantity of water to escape before the line could be shut off. At the time of the break, work in connection with the new subway to Harvard Square was in progress, and the watchman notified the headquarters of the maintenance force promptly and the gates controlling the flow of water were closed and pressure restored throughout the district in one hour and fifteen minutes. During this interval, however, water was escaping through the orifice in the pipe at a rate, roughly estimated, of 100 000 000 gal. per day, equivalent to 5 200 000 gal., which flooded streets and the basements of several buildings along its course to a lower level. An electric light pole was undermined and the wires fell across the trolley wires, interrupting the car service and making it dangerous to commence immediate repairs. After consulting the chief engineer, he agreed with the writer that it was better to wait until morning before starting the repair work. The line was again ready for use at midnight on December 25. The pipe that broke was a Class C, Metropolitan Water Works' standard, which requires a thickness of metal of 1.4 in. The pipe had been in almost continuous use since January 1, 1899, under a head of 144 ft., until it burst December 24, 1909. The piece blown off by the water pressure was approximately 7 ft. long and 4 ft. wide, with a developed surface of 25.4 sq. ft. The orifice through which the water escaped from the main was about 22.2 sq. ft. The pipe was cracked the entire length of the bottom. The pipe was found to be resting on a concrete duct which had been put in after the pipe was laid, and in order to make a closure it was necessary to remove about three quarters of an inch of this concrete duct before the new pipe could be sleeved in. Many of

Interior View of Break in 48-in. Metropolitan Water Works Supply Main, Commonwealth Avenue, Newton, November 6, 1915.



EXTERIOR VIEW OF BREAK IN 48-IN. METROPOLITAN WATER WORKS SUPPLY MAIN, COMMONWEALTH AVENUE, NEWTON, NOVEMBER 6, 1915.

the basements of the buildings in the immediate vicinity which were flooded contained very valuable goods. The cost of the repair work was $459.07. The cost of the damage to property was approximately $20 000.

Another serious break occurred in the 48-in. main supplying the city of Boston, in Clinton Road, Brookline, at 11.50 P.M., on December 4, 1913. It was necessary to operate five 36-in. valves and one 48-in. valve to shut off the flow of water. In the meantime, for nearly two hours, water was flowing from the orifice at the rate, approximately, of 80 000 000 gal. per day, equivalent to about 6 660 000 gal. The pressure in the city proper was reduced but did not fall below the ordinary pressure furnished during the day. The water flowed down Clinton Road for a distance of about 600 ft. and then across lawns of several private estates, washing lawns and excavating holes along the house foundations to a depth of three to five feet, covering an area of about 1.3 acres. After crossing the private estates, the water continued along Clark Road, removing surface material from the street and sidewalk. Again crossing private property, it undermined a small portion of the Boston & Albany Railroad, finally entering Village Brook, at a distance of about 2 500 ft. from the break. The water entered the basements of five houses, carrying considerable sediment, which was deposited when the water receded. This pipe line was acquired from the city of Boston in September, 1913. The line was laid in 1869 and placed in service in 1871. The greater portion of the line was laid between January 1 and April 1, 1869, and since the line was put in service, thirteen breaks have occurred. Three of these breaks occurred soon after the main was placed in service, and at that time the pressure did not exceed 10 lb. per square inch. On October 10, 1900, the pressure was increased about 10 lb., and during the following two months six breaks occurred, followed by another on June 29, 1901. During the past fifteen years two more breaks have occurred, one on December 14, 1907, and the other, just described, December 4, 1913. The pipes were designed to be about 1.4 in. in thickness and to weigh 8 045 lb. per length. Nearly all the breaks have occurred where the pipe was laid 9 to 14½ ft. below the surface of the ground, which leads to the inference that the weight of the material rather than

the internal water pressure has been the greatest factor in causing these breaks. Measurements were taken of the interior of the pipe, which gave an excess of horizontal over vertical internal diameter at the place where the greatest number of breaks have occurred, of ten-sixteenths of an inch for a maximum and one-sixteenth of an inch for a minimum, an average excess of nine-sixteenths of an inch.

Mr. Frederick I. Winslow, in referring to some of these breaks in an article in the *Engineering News* of July 3, 1902, called them seven mysterious breaks occurring on the Boston Water Works system.

On October 3, 1914, at 10.15 A.M., a 36-in. pipe in one of the two lines into which the 48-in. pipe line is divided where it passes under the Mystic River between Somerville and Medford, was broken by the Eastern Dredging Company's dredge accidentally dropping an 18-in. square, steel-pointed spud on to the pipe. The pipe line under the river is supported on single pile bents under each pipe. A piece of pipe 5 ft. long and 4 ft. wide was broken off. As a result, water flowed from an opening at an average rate of about 75 000 000 gal. per day, while the gates controlling the flow were being closed. The pressure on the northern low-service district was reduced by 25 to 35 lb. below normal for about thirty-five minutes. In removing the broken pipe, it was necessary to blast with dynamite, closure being made with two short lengths sleeved in, the joints being made with lead wool by a diver. The accident occurred in the river channel where there is about twenty-two feet of water at high tide.

On November 6, 1915, a break occurred about 5.30 A.M. on the 48-in. Weston Aqueduct supply main on Commonwealth Avenue, at Auburn Street, Newton. A loss of pressure at the pumping station was noted and the maintenance force notified. The men were assembled, but no report was received of a break on the system. As a break on the Boston mains would show a loss of pressure at the station, inquiry was made of the Boston department, but no report had been received of any break on that system. At 6.40 A.M., no word having been received from local officials, men were sent out to examine our Venturi meter registers and at once found the trouble was on the supply line. A truck, with

men, was at once sent over the line and the break located and the line shut off at 7.45 A.M. The water from this break flooded an area of 7.6 acres, including the basements of six houses, the basement floor of a section of a church, and undermined a part of the track of the Boston & Albany Railroad, also causing more or less damage to the property of fifteen others residing in the vicinity, which required considerable work regrading lawns and shrubbery beds and rebuilding a tennis court. The water escaped from an orifice in the pipe at a rate, roughly estimated, of about 80 000 000 gal. per day, equivalent to a total of 7 500 000 gal. The pipe that broke was Class B, Metropolitan Water Works' standard, which requires a thickness of metal of 1.25 in. The pipe was laid in 1902 and has been in almost continuous service since December 29, 1903, under a head of 145 ft. The pipe was cracked the entire length, and the piece that was blown off by the water pressure was approximately 10 ft. long and 3 ft. wide. The orifice through which the water escaped from the main was about 18 sq. ft. The pipe was covered to a depth of 14 ft. and was crushed by the heavy weight concentrated on the small bearing surface where the pipe rested upon a projecting point of rock which had not been excavated to a sufficient depth when the pipe was laid.

Breaks that occur on local systems are not a disturbing factor to the supply mains of the Metropolitan Works, except those that occur on the larger mains of the Boston system, and during the period covered by this paper there have been thirteen breaks in Boston caused by the pipe being supported at one point on solid foundation, such as subway roofs, timbers, manholes, and sewers.

The total amount paid out for damages on account of the breaks on the Metropolitan Works is approximately \$37 000, \$20 000 of which was for the Harvard Square break, leaving about \$17 000 for the remaining twenty-four breaks, approximately \$4 000 of which was paid on account of seven breaks on existing mains taken as part of the Metropolitan Water Works system.

The total cost of stock used on the distribution system of the Metropolitan Water Works, exclusive of the pipe taken from existing works, including pipes, valves, specials, etc., is \$2 581 000, which represents the cost of material in the 98.57 miles of mains laid under the direction of the Metropolitan Board.

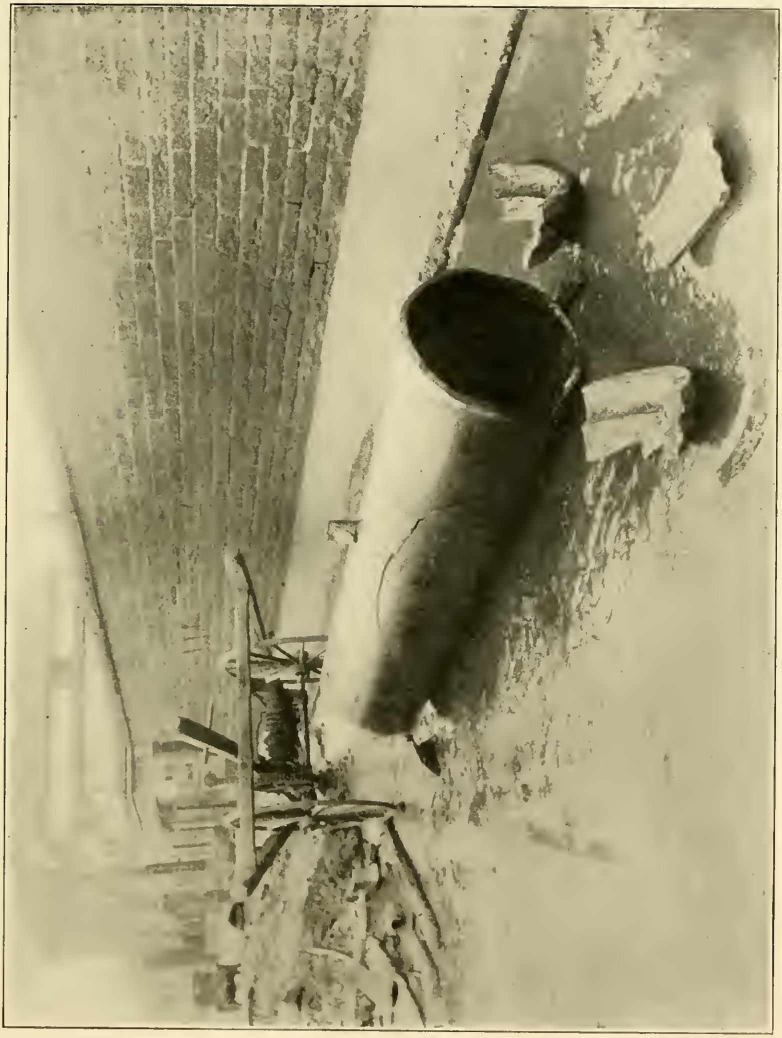
It is the writer's opinion that the time has come when, especially in the larger municipalities, there should be a more thorough study of the conditions of the streets before public service corporations are granted permits for concrete structures. The writer would even go further and require public service corporations laying solid structures under large supply mains upon which a municipality must depend for its supply for fire protection and domestic use to give notice to those in charge of the maintenance of those mains that the work was to be done so that the work could be thoroughly inspected, as, at present, unless the pipe lines are patrolled daily, we find, many times, evidence where work has been done and covered up without our attention being called to it.

The problem of furnishing an unfailing supply of water for various requirements of the larger municipalities, especially in the case of breaks, demands an increasing vigilance on the part of trained men, who must, at all times, be prepared to meet emergencies which are sure to arise. If a serious loss of life and property is to be avoided, intelligent and conscientious work on the part of every employee connected with the water department is a necessity. The efficiency of water-works service is being greatly promoted by the increased use of automobiles for the transportation of men and supplies. The Metropolitan Water Works has recently added to its equipment two emergency service trucks, equipped with gate-operating device, and men will be stationed on duty, at all times, who are capable of operating these when emergencies arise.

Discussion.

Mr. Saville. We have had several breaks in the last two years, on large size pipes. I have three photographs I would like to put in as evidence in support of Mr. Killam's statement against the rigid support. The first break is on a 24-in. line that encircles the city as a fire line. The pipe is rigidly supported on one side by a sewer manhole. A trench had been dug on one side, and the filling was loose. The pipe dropped under a gas main and was backed with cement on one side. Some settlement occurred and the pipe was cracked the entire length.

Mr. Ackerman. I only wish to cite an instance or two that



BREAK IN 24-IN. PIPE, HARTFORD, CONN.

happened in the city of Auburn, N. Y., and illustrate that it is not always a case of rigid support. In one rocky section of our city during the construction of sewers, there was much blasting. The main sewer had been placed in, and I supposed the danger

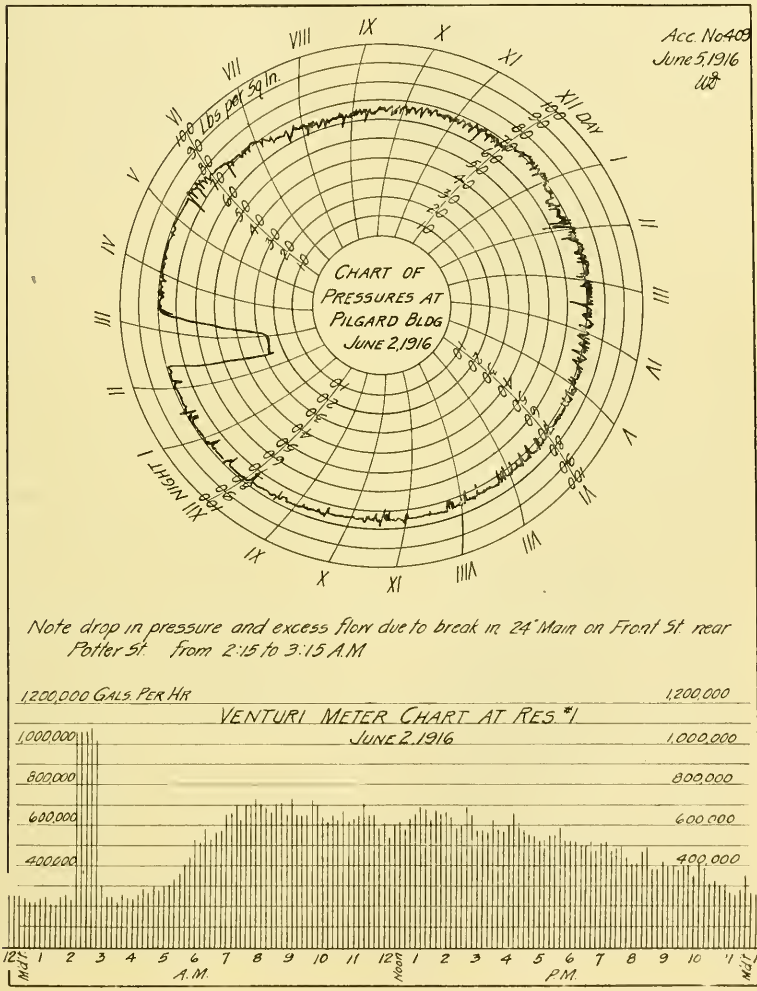


FIG. 1. DROP IN PRESSURE AND INCREASE IN FLOW DUE TO BREAK IN 24-IN. PIPE, HARTFORD, CONN.

was all over, but in placing laterals an Italian had been attempting to connect a trench with a lateral of a sewer and had been using dynamite very freely, and he came to a new kind of rock which

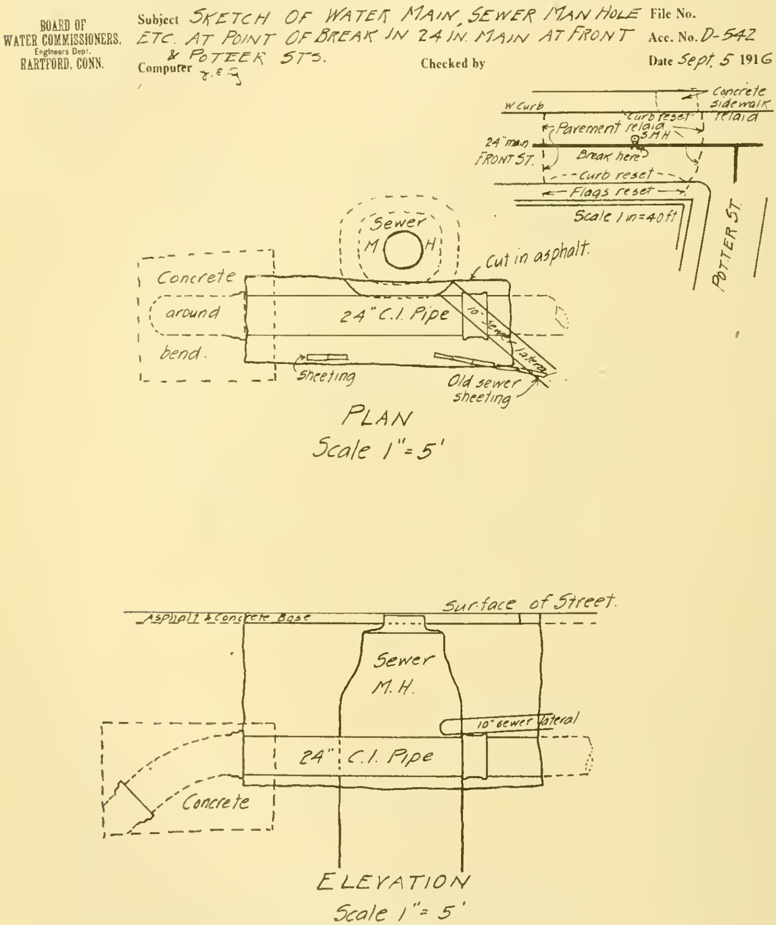
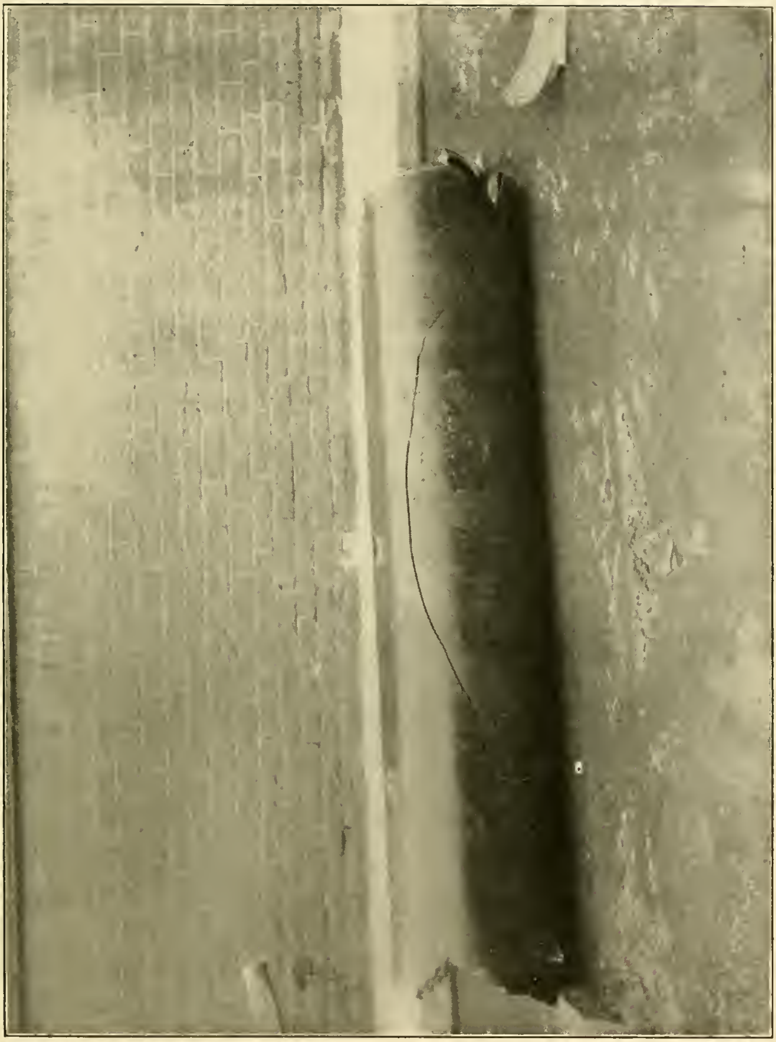


Fig. 2. Location of 24-in. Pipe, Hartford, Conn.

apparently he couldn't do anything with, so he put a stick of dynamite under it and touched it off. It happened that that peculiar thing he couldn't get out of his way was a 12-in. water main. He got it out of his way, and of course the residents in the vicinity got a lot of water. The last seen of the Italian he was going in a direction as far away from the scene as possible.



Break in 24-in. Pipe, Hartford, Conn.

I might cite one other instance that was very peculiar. An old water course had been made into a sewer, and a fill had been made on that street. A few years later, a line of pipe was placed over this, and that line of pipe had been in service for nearly thirty years. On Hallowe'en, at about two o'clock in the morning,—the usual time,—a party of four people, two ladies and two gentlemen, came to a street intersection, and they saw large quantities of water coming down the street. There was so much they did not want to make the crossing, and they walked up the street a short distance, and the water was coming up at the curb line. There was just a short space between the sidewalk and the curb. They stood there momentarily to see what the trouble was, and while the four of them stood there, sidewalk, people, and all went into a pool that had been made, and two of them came near drowning. We had to pay for suits of clothes, doctors' bills, and fancy dresses.

Mr. Desmond FitzGerald. While it is undoubtedly true that the great majority of breaks in large mains arise from the nature of the supports, there are other causes. One to which I should like to allude, and which is not often referred to, is the danger of breaking a main, at some weak spot, by the too rapid filling of the main, when it has been emptied. Great caution should be used in the first filling of a main and also whenever it has been emptied. If the air has not full opportunity to escape, it will become compressed and react upon the pipe. I have always been very careful in performing this operation, especially towards the latter part of the process, when the main has been nearly filled, and even with ordinary care I have seen the water mount much higher than the source of supply in great surges which sometimes cause considerable anxiety.

Once in my own experience when some other officials attempted to let the water on too suddenly to a 48-in. pipe in the bed of Reservoir No. 1 of the Boston Water Works, the whole pipe for a short distance was blown out of its bed and up into the air, above the surface of the water.

Particular care should also be taken in filling mains from gatehouses. I have seen the roof of a gatehouse nearly blown off by return surges, which are at times even dangerous to those who are doing the work.

ELECTROLYSIS — TROUBLES CAUSED THEREBY AND REMEDIES WHICH MAY BE APPLIED.

BY ALBERT F. GANZ, PROFESSOR OF ELECTRICAL ENGINEERING, STEVENS INSTITUTE OF TECHNOLOGY, CASTLE POINT, HOBOKEN, N. J.

[*Read March 14, 1917.*]

Introduction.

Electrolysis is the process of decomposing a chemical compound by means of an electric current. Electrolysis, in the sense in which it will be discussed here and in which you are particularly interested, refers to the corrosion of underground metallic structures, such as iron and lead pipes, by stray electric currents which reach these structures and flow to surrounding soil. Soil, when entirely dry, practically does not conduct electric current. Pure water likewise has such a high electrical resistance, compared with iron or lead, that it may be considered a non-conductor. Water is, however, readily made conducting by the addition of even very small amounts of salts, and conduction through water is therefore always electrolytic. Soil in its natural state is always moist, and on account of dissolved salts, such as chlorides, nitrates, etc., which are always present, is an electrolytic conductor.

Electric current may be conducted by metallic conduction or by electrolytic conduction. Metallic conduction occurs when an electric current passes through a metal, and is characterized by the fact that no chemical change is produced in the conductor, the only effect being the production of heat. Where electric currents, therefore, pass through metallic conductors, such as copper wires, rails, or pipes, they produce no change in these conductors except to raise their temperature. Electrolytic conduction occurs when an electric current passes through an electrolyte, and is characterized by the fact that chemical decomposition occurs at the electrodes where the current enters and leaves the electrolyte.

When an electric current flows from a pipe or other metallic structure to surrounding soil, chemical decomposition of the metal will take place, resulting in corrosion of the pipe or structure. Concrete, when buried in earth, is moist, and it then becomes an electrolytic conductor, so that an electric current flowing from iron to surrounding concrete will corrode the iron by electrolysis.

The mass of a metal corroded by electrolysis in a given time depends only on the "current," and, with the current densities and other conditions usually found in the case of underground pipes, is equal to that calculated by Faraday's law. Iron is oxidized by electrolysis at the rate of approximately 20 lb. per year for every ampere of current flowing from the iron to surrounding soil. Under some conditions, particularly with very small current densities, this corrosion may be considerably greater, while with larger current densities than the above, this corrosion may be considerably less than the theoretical rate. The actual rate may vary in practice from one-half to one and one-half times the theoretical rate. Lead is oxidized by electrolysis under ordinary conditions in soil at a rate equal to approximately 74 lb. for every ampere of current leaving the lead in one year, and this theoretical rate may also vary somewhat in practice. The amount of corrosion produced by electrolysis is independent of the voltage, except in so far as this determines the amount of current flowing, and the smallest fraction of a volt can produce corrosion from electrolysis under suitable conditions.

The rapid corrosion by electrolysis from external currents is usually localized, and results in pitting of the metal. Such pitting may, however, in some cases also result from ordinary soil corrosion, so that the appearance of a corroded metal structure does not by itself afford conclusive evidence as to whether or not the corrosion was produced by electrolysis from external electric current.

Where the direction of current flow between an underground pipe and surrounding soil reverses more or less continually, it has been found that the corrosion occurring during the time that current flows from the pipe is largely offset by a reversed action which occurs during the time that current flows to the pipe. The resultant corrosion by electrolysis from periodically reversed direct

current is for this reason much less than when the current always flows in the same direction, and this corrosion decreases with increasing frequency of reversal. Investigations have shown that even if such reversals occur only once in twenty-four hours the actual amount of corrosion for iron is only about one fourth of what would occur if the same amount of current always flowed from the pipe to surrounding soil.

When an alternating current of commercial frequency flows between a pipe and surrounding soil, the amount of corrosion produced by electrolysis is of the order of one per cent. or less of the corrosion which would be produced by an equal direct current flowing continuously from the pipe to the soil.

Sources of Stray Currents which may Produce Electrolysis.

Electrical distribution systems which are grounded at two or more points will, by the law of divided circuits, cause currents called "stray currents" to shunt through the earth between the grounded points, and these stray currents frequently reach underground metallic structures and corrode them by electrolysis. In practice, it is found that the most important sources of stray electric currents, which so endanger underground structures, are direct-current electric railways, which use the running tracks in contact with ground for part of the electric circuit.

For such railways, it is the common practice to supply current to the cars from an overhead trolley wire or from a third rail, and to return this current to the power station through the running tracks, supplemented in large systems by return feeders. A single-trolley electric railway is illustrated in Fig. 1. In this figure the path of the electric current from the positive terminal of the generator through the circuit and back to the negative terminal is shown. In such a trolley system the running tracks consist of rail lengths mechanically fastened together by fish plates of steel bridging across the rail ends and bolted to both rails. Such fish plates while mechanically fastening the rail lengths together do not afford good electrical connections between the successive rail lengths. For this reason, copper wires or straps, called rail bonds, are generally used to bridge across the abutting ends of the rail lengths for the purpose of affording a good elec-

trically conducting path between successive rail lengths. The two rails of a single-track road, or the four rails of a double-track road, are also generally connected together at frequent intervals by cross bonds so that the two or the four rails may be available for the return of current. Instead of using copper rail bonds, the rail

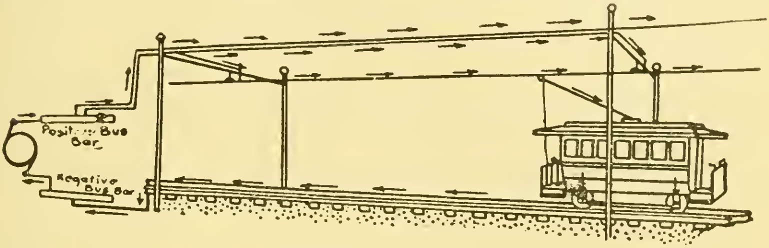


Fig. 1. Diagram of Single-Trolley Electric Railway showing Path of Current from Generator through Positive Feeders, Trolley Wire, Car, and Rails.

ends are sometimes welded together, or soft-steel plates are welded across each side of the abutting rail ends, thus forming both a strong mechanical and a good electrically conducting connection between the successive rail lengths. To give some idea of the conductivity of steel rails, it may be stated that a single rail weighing 90 lb. per yard has about the same conductivity as a copper wire one inch in diameter. Thus the two rails of a single-track line or the four rails of a double-track line laid with 90-lb. rails and well bonded afford a good conducting path for electric current.

In the simplest form of single-trolley railway, shown in Fig. 1, the rails are connected to the negative terminal of the generator at the power station, and the only path for current to return to the power station is by way of the running tracks. If the running tracks are laid upon wooden ties above ground with broken stone for road ballast, as is common on steam railroads which run on their own right-of-way, the rails do not come in direct contact with ground, and the return current will be practically confined to the running tracks. If, however, the running tracks are laid below ground so that the top of the rails is level with the surface of the street, as is common in cities, then the rails will be exposed for a considerable area to contact with ground. If the tracks are laid on a concrete base, a considerable area of the rails will simi-

larly be in contact with the concrete. Since both damp soil and damp concrete are, under ordinary conditions, conductors of electricity, part of the current returning through the rails will shunt from the rails through the neighboring earth, as is illustrated diagrammatically in Fig. 2. It will be seen that with the usual connection of positive terminal of the generator to the trolley wire, and the negative terminal to the rails near the power station, the current will leave the rails for earth at points distant from the power station, and return to the rails in the neighborhood of the power station, in its path back to the negative terminal of the generator. Since every electric circuit must be completely closed,

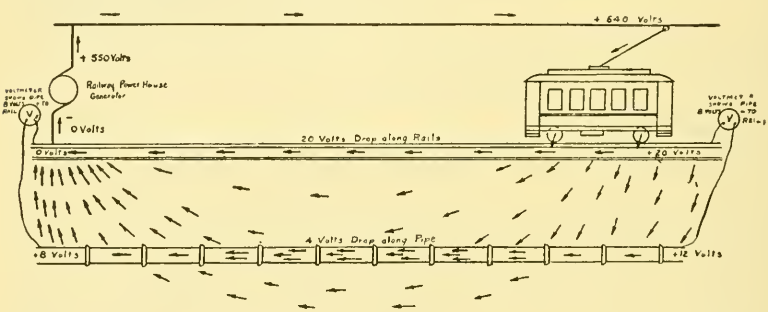


FIG. 2. DIAGRAM SHOWING STRAY RAILWAY CURRENTS WITH ASSUMED DISTRIBUTION OF POTENTIALS CAUSED BY THESE CURRENTS.

all current escaping through earth must again leave earth to return to the dynamo so as to complete the electric circuit. Where underground metallic structures, such as gas or water pipes, lie in earth in the path of these stray currents, and where these pipes have electrically conducting joints, — such as lead-calked joints or screw-coupling joints, — current will flow from earth to such pipes and flow on such pipes towards the power station. In the neighborhood of the power station this current will leave the pipes to return through earth and the tracks to the negative terminal of the generator, as shown in Fig. 2.

If the negative terminal of the generator or negative bus-bar is connected to the rails at points some distance from the power station by means of insulated negative return feeders, then at

such connection-points the rails will be rendered negative in potential to earth, and currents will tend to flow from underground pipes through earth to return to the rails in the neighborhood of these connections. Such stray railway currents on pipes will therefore tend to leave these pipes to return to the rails in all regions where these rails are connected to return feeders.

It has been suggested to reverse the usual arrangement of trolley system and make the rails the positive conductor instead of the negative conductor. With the rails the positive conductor stray current flows to underground pipes in the vicinity of the power station, and leaves these pipes over widely scattered areas so that the density of the current leaving will be relatively small. By this arrangement the acute danger which with the usual polarity exists in the neighborhood of each station is removed, but electrolysis troubles are spread over a greatly distributed area. The total amount of electrolysis must, however, be the same whether the rails are the negative or the positive conductor, since the stray currents through earth are simply reversed in direction but not changed in magnitude. This arrangement has been tried in several places and has been used in one large city for about three years. I have had occasion to make tests in this city and have found that trouble from electrolysis is developing in outlying sections, and some trouble from corrosion of service pipes in such outlying sections has already been found.

It must be noted that, while ordinary soil is a conductor of electricity, its electrical resistivity compared with metals is enormously high, being of the order of millions of times the resistivity of iron. Resistance, however, varies inversely as the cross-section of a conductor, and with the large surface of rails exposed to the earth, the cross-section of the path of current through earth is enormously great compared with the cross-section of the path of current through the rails. As a matter of practice, it is often found that where the rails in contact with earth are used alone for the return of current, a considerable portion of the total current leaks from rails through earth.

The leakage of current from the rails of electric railways, producing stray currents through earth and on underground piping, does not constitute a source of loss to the railway company, as, for

instance, would be the case with leakage of gas or water. On the contrary, by allowing the current to return by earth and underground pipes as well as by way of the rails, the total conductivity of the return circuit is increased, and the voltage loss in the return of this current is decreased, so that there is an actual saving of power for the railway company.

Alternating currents have been used for some years past in a number of electric railways employing the running tracks as a part of the electric circuit, and where these tracks are in contact with earth, stray alternating currents through earth are produced. Where an alternating current flows from iron or lead to surrounding soil, corrosion from electrolysis may also be produced, but this proceeds at a relatively very slow rate, as already explained. With alternating currents, electrolysis is, however, produced at the two electrodes, instead of at one electrode only, as with direct current. So far as the writer is aware, no damage from electrolysis due to such stray alternating railway currents has been reported to this date. This may be due to the slow rate at which corrosion is produced by alternating currents, together with the fact that most of these railways are of relatively recent installation. It may also be due to the fact that stray direct currents are nearly always present with the alternating currents, and the effects of these direct currents may have inhibited or masked the effect of the alternating currents. It is therefore not possible at this time to draw a positive conclusion as to the danger from stray alternating currents.

General Effects of Stray Electric Currents on Underground Piping.

The current flowing through the rails from the trolley cars back to the power station produces in these rails a drop in potential; that is to say, points in the rail away from the power station have a positive potential with reference to the rails at the power station. Since potentials are measured relatively, it is convenient to consider the negative terminal of the dynamo, which is assumed connected to the rails at the power station, as at zero potential. The distribution of potentials in the rails of a simple electric railway system and in the underground piping is illustrated in Fig. 2, in

which convenient values have been assumed. It will be noted that the underground pipes are negative to the rails at points away from the power station, and positive to the rails near the power station. It is also seen that the negative potential of the pipe, plus the drop on the pipe, plus the positive potential of the pipe, equals the drop in the rails. In the case assumed, there is a potential difference of 550 volts maintained at the power station; of this, 10 volts is lost in the trolley wire, 520 volts is used by the motors of the car, and 20 volts is left to bring the current back to the power station. If the negative bus-bar and the rails at the power station are considered as at zero potential, the rails at the car in the assumed case will have a potential of 20 volts. Thus, for practical purposes, the earth with its underground pipes is subjected to a potential difference of 20 volts, and the amount of stray current produced is that due to these 20 volts. If the rails are laid in the usual way, that is, in contact with ground, the 20 volts in the rails will send some shunting current through the earth and on the underground pipe as shown in the diagram. Under the assumed conditions, there is a drop of 8 volts from the rails to the pipe near the car, a drop of 4 volts in the pipe itself, and a drop of 8 volts from the pipe through earth to the rails at the power station. It is therefore seen that it is the voltage drop in grounded rails caused by the return current which is the cause of stray currents through earth.

From the explanation of metallic and electrolytic conduction given in the first part of the paper, it will be understood that where stray currents flow on underground pipes they do no harm except where they leave the pipes to flow to the surrounding soil. At such points corrosion of the iron from electrolysis will take place. In the simplest case, illustrated in Fig. 2, current flows from rails through earth to the pipes at points distant from the power station, flows on the pipes, and leaves the pipes to return through earth to the rails in the neighborhood of the power station. Where the current flows from the rails to earth, the rails will be corroded, and where the current flows from the pipes to earth, the pipes will be corroded. If the pipe line is a uniform electrical conductor, and the relative arrangements are as shown in Fig. 2, then the pipes will be corroded only in the neighborhood of the power sta-

tion. If, however, the pipe line is not a uniform conductor, — as, for instance, if there are one or more high resistance joints in this pipe line, — then the current on the pipe will shunt around such high-resistance joints and produce oxidation or corrosion on the positive sides of the joints. Where there are two or more underground piping systems, it also frequently happens that current shunts from one system to another through the intervening soil, producing electrolytic corrosion where the current leaves the pipes. Such shunting currents are often caused by accidental high-resistance joints in one of the pipe lines, and such shunting may occur anywhere and without reference to the location of the railway power station. Where a direct-current trolley system passes through a town which has an independent piping network, and where the power station supplying the trolley line is in some other locality, then if stray electric currents are produced by the trolley line where it passes through the town, they will flow on the piping system, making this piping system positive to earth and to rails at points nearest the railway power station, and negative at points farthest away from the power station. In this case electrolysis of the piping will be produced at the ends of the piping system which are nearest to the power station.

Where current leaves a wrought-iron or steel pipe for earth, the oxide of iron resulting from electrolysis becomes diffused through the earth, and streaks of iron oxide can generally be found in the surrounding soil. Electrolysis of wrought-iron or steel pipes usually results in pits which eventually go entirely through the wall of the pipe. It has frequently been found, in practice, that where a gas service pipe lies in clay or other tightly packed soil, it may be pitted through in many places without giving any external sign of leakage, because the soil surrounding the pipe maintains it gas-tight. When cast iron is corroded by electrolysis, the oxides of iron mixed with graphite usually remain in place, leaving the outside appearance of the pipe unchanged. This material, resulting from the electrolysis of cast iron, usually has the consistency of hard graphite, and can be cut with a pocket knife. There have been many cases in which a cast-iron main was carrying gas or water without any apparent leak, where a light blow with a hammer drove a hole right through the pipe. Here

the electrolytic action had corroded the iron entirely through the pipe, and the oxide of iron had remained in place, and, together with the surrounding soil, had prevented the pipe from leaking. Whether or not the mixture of iron oxide and graphite resulting from electrolysis remains in place so as to maintain a pipe gas- or water-tight, depends upon the surrounding soil conditions. It is therefore seen that an underground piping system may be suffering severely from electrolysis without giving any outward sign of the damage. A physical examination with a test hammer is required in the case of cast-iron pipe to establish definitely whether or not it has been damaged by electrolysis.

For a given current leaving a pipe, there is practically no difference between cast iron, wrought iron, and steel, in the amount of iron destroyed. The electrical resistivity of cast iron is, however, about ten times as great as that of wrought iron or steel, and the usual lead joints in cast-iron pipes also have a resistance which is many times greater than the screw-coupling joints used with wrought-iron and steel pipes. A given voltage drop through earth will therefore cause a much smaller current to flow on a cast-iron pipe than on a wrought-iron or steel pipe, thus making cast-iron pipes much less subject to electrolysis than wrought-iron or steel pipes.

Electrolysis Surveys on Underground Piping Systems.

In order to determine the electrolysis conditions of an underground water-piping system, a potential survey and a current survey are generally made. Where it is also desired to determine what remedial measures should be applied for protection against electrolysis, tests of the current and voltage distribution in the grounded circuits of the electric railway system by which the stray currents are produced should also be made.

In the potential survey, voltage measurements between the water pipes and trolley rails and between the water pipes and all other neighboring underground piping and cable systems are made at a number of selected locations. They should preferably be made simultaneously between all of the structures tested at any given location, and either indicating or recording voltmeters may be employed; but the tests should be made for a sufficiently long

period at each location to cover a complete cycle of car operation. Where the water pipe itself is not exposed, connections for these voltmeter measurements may be obtained by means of house service pipes, which are satisfactory for these tests, because the voltmeter has a high resistance and takes only a very small current.

The current survey consists of measurements of current flow on pipes at selected locations in the piping system. To determine the current flowing on a pipe, the voltage drop between two points on a continuous length of pipe is measured by means of a millivoltmeter. From this voltage drop and from the resistance of the included pipe, which may be obtained from published tables, the strength of the current is computed. To measure this drop it

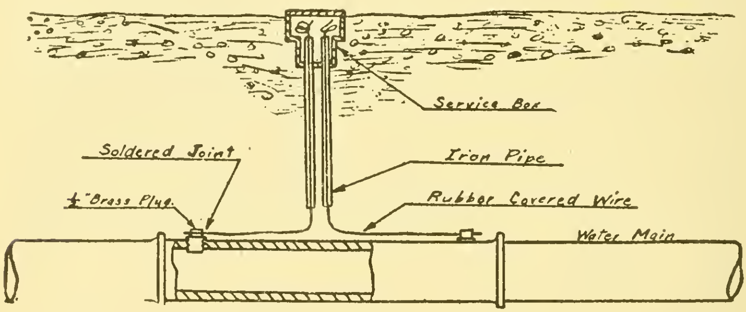


FIG. 3. PERMANENT ELECTRICAL TEST WIRES ATTACHED TO MAIN AND BROUGHT TO SURFACE OF STREET THROUGH SERVICE BOX.

is necessary to expose the pipe and to make good electrical contact between the millivoltmeter leads and the pipe. The best contact for these current measurements is obtained by soldering the connecting wires directly to the pipe or to two brass plugs screwed into the pipe. This method is particularly advantageous when readings are to be taken over a considerable time, and it is customary to use rubber-covered wires and bring them to the surface of the street, leaving the ends in service boxes, which then form permanent stations for electrical measurements. This is exceedingly convenient because it is then possible to make current measurements on the pipe without again making an excavation. Such permanent contact wires are illustrated in Fig. 3.

It should be noted that small potential differences, such as 0.1 millivolt or less, may be caused by local galvanic or thermal action. Where such small values are found in a test for drop on a pipe, a careful investigation should be made to ascertain whether the observed potential difference is actually drop due to current flow. The writer has found that such small potential differences are a frequent source of error when tests are made by persons who are not experienced in making such electrical measurements.

Since current destroys metal only where it leaves for soil, it is important to know where the current leaves a pipe. Current measurements on pipes are therefore frequently made at two or more stations simultaneously in order to determine the change in current on the pipe between the stations. For these current measurements, indicating or recording millivoltmeters are employed. By comparing the characteristic variations of currents and voltages measured for twenty-four-hour periods at selected locations with the characteristics of the neighboring electric railways, it is often possible to identify the source of the stray current flowing on a pipe.

From a study of the results of the potential and current surveys it can be determined where current is leaving the piping, and at a number of such points excavations should then be made and the exposed pipe examined with a test hammer for corrosion of the iron. Where corrosion and pitting is found at points where current is leaving the pipe, it may be taken as evidence that at least part if not all of the corrosion has been caused by electrolysis, because it has been conclusively proven that whenever current flows from iron to surrounding natural soil, corresponding corrosion of the iron by electrolysis takes place.

From a complete and properly analyzed electrolysis survey, a great deal of good can generally be accomplished. It will not always be possible to remove all stray currents from the pipes, but measures will be indicated by which the conditions can be greatly improved, and points of greatest danger will be located.

Remedial Measures Applied to Pipes.

Attempts have been made to protect underground pipes from electrolysis by insulating them from earth by paints or dips.

Practical experience as well as a large number of tests have, however, shown that no dip or paint will permanently protect a pipe against electrolysis in wet soil. The first difficulty is to apply the paint so as to form an absolutely perfect coating, and the second one is to prevent mechanical damage to the coating during shipment and installation of the pipe. In the case of paints which are applied with a brush, these afford only a very thin coating over the metal, and where stray currents are present, the effect of these currents and of the moist soil is to cause the coating to disintegrate and disappear rapidly. A large number of experiments which I have made have shown that such paints will disintegrate not only where the current flow is from the metal to earth, but also where the flow is from earth to the metal. Experience further shows that even where coatings of paints or dips are apparently intact, electrolytic action is not always prevented, and, in fact, very serious electrolytic pittings have been found under apparently good coatings. It has been found that in most cases the applied coatings have either been completely destroyed by the effects of the wet soil and the electric currents, or defects in the coating have developed, causing concentrated corrosion at such defective spots. Where it is attempted to apply a heated material like pitch or asphaltum to a cold pipe, it is impossible to completely cover the pipe. Pitch and similar compounds have been applied to pipes with wrappings of jute or of some similar material. A number of layers can be applied in this way so as to build up any desired thickness of insulating covering. Such covering if sufficiently thick will afford protection against electrolysis, provided that it is mechanically perfect. The great difficulty in practice is to apply such a covering without leaving defective spots through which moisture will have access to the metal of the pipe.

Pipes which are covered with imperfect insulating coatings, or coverings exposing bare spots of metal, are in much greater danger from electrolysis where positive to earth than are bare pipes, for the reason that the stray currents will leave only from these bare spots, and here produce concentrated corrosion. The writer has seen cases where a pipe coated with an imperfect insulating covering was pitted nearly through in one year, whereas

a bare pipe in the same locality was very much less affected, because the corrosion was distributed over a larger surface.

One form of insulating covering which appears to afford complete protection is a layer of from one to two inches of a material like coal-tar pitch, parolite, or asphaltum, of such a grade that it is not brittle, and so will not crack, but yet is hard enough to remain in place. The best way to apply such a layer is to surround the pipe with a wooden box, support the pipe upon creosoted blocks of wood or upon blocks of glass, and then fill the space between the box and the pipe with the molten material. When applying this material, great care must be exercised to avoid getting stones or dirt into the mixture, and also to avoid leaving bare spots on the pipe. The cost of carrying out such an installation is prohibitive, however, except in very special cases, such as that of service pipes in very bad localities, or that of very important individual pipe lines of small or medium size. Embedding a pipe in cement or concrete, even if this is several inches in thickness, will not protect it from electrolysis, because damp cement or concrete is an electrolytic conductor.

Insulating covering, even if imperfect, is useful on pipes in negative districts where current flows from earth to the pipes, because this covering will increase the resistance from earth to the pipes and thereby correspondingly reduce the amount of current reaching the pipes.

Current flow on metallic pipe lines can be practically prevented by using a sufficient number of insulating joints. A pipe line laid with every joint an insulating joint has a comparatively high resistance, and no substantial current can flow on such a line. It is sometimes possible in the case of individual pipe lines to use comparatively few insulating joints to break up the electrical continuity of the line and substantially protect it from electrolysis, but such joints must be installed only after adequate tests have shown that sufficient current will not leave the pipe on the positive side of any joint to flow to earth and do serious damage by electrolysis. Insulating joints in pipe lines should not be confined to the positive areas, but should be installed in all places along the pipe line where there is any considerable potential gradient in the earth parallel to the pipe. The frequency with which insulating

joints must be installed in a pipe line in order to assure reasonable protection from electrolysis depends upon the potential gradient through earth and upon the electrical resistivity of the earth. The effective resistance of a short insulating joint is practically the same as that of a long joint, but a long insulating joint gives a more even distribution of leakage current than a short joint. Hence a long insulating joint is to be preferred where there is considerable potential difference across the joint, or where the resistance of the surrounding earth is low. The effect of a long joint can be practically secured from a short insulating joint by surrounding the joint and the pipe for from 5 to 25 ft. on each side of the joint with a heavy layer of insulating material.

Where service pipes are endangered by current which flows to them either from the main or from house piping, such current flow can be prevented and the service pipes protected by placing insulating joints in them at the main or in the building, or at both locations.

Insulating covering and insulating joints can be applied in special cases to individual pipes, but cannot ordinarily be applied in an extensive manner to a piping network.

A method of mitigating electrolysis which has frequently been employed in this country is pipe drainage. This consists of connecting the pipes to the railway return circuit at a sufficient number of points to render the pipes at all points negative to the electric railway tracks. Electrical drainage was first applied to lead cable sheaths, and the success in protecting cable sheaths in this manner led to the attempts to apply the drainage method also to pipes. There are marked differences, however, between an underground piping system and a lead cable system, which render the piping system much less suited to electrical drainage. The principal difference is that cable sheaths are continuous electrical conductors, while pipes may be more or less discontinuous, owing to the presence of high resistance joints. Another difference is that the lead cable sheaths are relatively small and are carried in ducts, which are mostly non-metallic, so that only a part of the surface of the cables is grounded, whereas underground pipes are buried directly in earth and generally present enormous contact areas to earth. The result is that, when electrical drainage is

applied to pipes, the currents on the pipes are very greatly increased. This increases the danger of current shunting around high resistance joints or leaving the pipe on the positive side of a joint to flow to other structures.

Draining the piping system to the negative bus-bar, when applied as the principal means for mitigating electrolysis, always largely increases the total current flowing on the piping system. When two piping systems, such as a gas and a water piping system, are drained to the negative bus-bar, large currents are caused to flow not only on the water and gas mains, but are frequently also caused to circulate between the gas and water mains through house service connections, because of varying resistances in the pipe joints. Such circulating currents are a serious fire hazard to the buildings through which they pass. Large currents on mains are also dangerous in cases where repairs are being made, because when a pipe carrying a large current is disconnected, an electric arc is produced at the point of separation. I have heard of numerous cases where such arcing set gas or oil on fire, and caused not only damage to property but serious injury to workmen. In many cases where pipe drainage is used, such large currents flow on the pipes that it is not safe to disconnect a pipe without first connecting a copper wire jumper across the proposed break.

Generally the only electrical measurements which are made before and after a system of pipe drainage has been installed are measurements of the potential difference between pipes and the rails. These measurements are ordinarily plotted on a map of the railway system, the values of the potential differences being laid off as normals to the railway lines, and these normals are connected by straight lines. The areas indicating pipes positive to rails are then colored red, and the areas indicating pipes negative to rails are colored blue. Before the pipe drainage is installed there are generally large red areas, indicating pipes positive to rails, while after the drainage has been installed there are only blue areas. The conclusion is then drawn that since the map giving the measurements after the drainage has been installed shows no red areas, all electrolysis troubles have been eliminated and the piping system is now safe against destruction by electrolysis. This would be true if the piping were a continuous and uniform

electrical conductor, and if there were no other underground metallic structures in the earth in the same locality. In any considerable network of underground pipes, there are always joints of widely varying resistances and generally many joints of high resistance, so that current instead of flowing continuously along the pipes may jump around high resistance joints or from one part of the network to another part. The blue areas on the map showing the potentials of the pipes referred to rails of course do not show this. Further, since there are always other underground structures, such as pipes or cables, present in the earth, current may flow between the various structures. The blue colored map also fails to show this. In my opinion, a pair of maps, as described above, shown for the purpose of proving that electrolysis has been eliminated on any underground system, are, to say the least, misleading. The complete data from which to judge the effectiveness of a drainage system would involve the results of many other tests, particularly of currents on pipes, of drop across joints in the pipes, and of potential differences between the drained pipes and all other neighboring underground structures. These additional measurements should be made at a large number of well-distributed locations. Owing to the inaccessibility of the pipes, it is generally impossible to make such tests, so that complete data on a system which is drained cannot be practically obtained.

Once electrical drainage is applied, it is usually found that thereafter everything is left to take care of itself, and no attention is paid to the railway return circuit. The writer experienced a most striking example of this in a city in the northern part of New York State a few years ago. It was reported that persons received electric shocks by touching water and gas pipes. Investigation showed that in the neighborhood of the railway substation, where the worst trouble had been experienced, the gas pipes were from 50 to 100 volts positive in potential to the water pipes. Tests made on the tracks in the neighborhood of this station showed practically no current flowing in the rails. Further investigation showed that the water pipes were connected to the negative bus-bar in the station by a large copper cable, and that this cable was draining the entire station load from the water pipes to the negative bus-bar. Still further investigation showed that the con-

nection from the negative return cables to the tracks, directly in front of the substation, had been corroded off so that there was no metallic connection whatever from the tracks to the negative bus-bar, and all of the current was forced to return by way of the earth and underground structures, and finally by the water pipe drainage cable to the negative bus-bar. This condition of affairs had existed for a number of weeks and had not been discovered by the railway company.

When electrical drainage is applied to a single system of underground pipes, without making a complete investigation of the effects of possible high resistance joints, etc., the installation may be made at relatively small cost, and, when so applied, it usually relieves the acute danger from electrolysis in the immediate neighborhood where the drainage connections are made. Both of these considerations have served to favor the electrical drainage system. However, a single drained underground piping system becomes a source of serious danger to other systems. If electrical drainage is applied comprehensively to all underground metallic systems, it will not only be found very expensive to install but, likewise, expensive to maintain, because as railway and piping systems are changed, the drainage system must also be changed accordingly. The large increase in current on underground structures produced by electrically draining them also brings about dangerous conditions at scattered and unknown places, which is a serious objection to this method. A further and perhaps the most serious objection to the drainage system is that sufficiently complete tests cannot be practically made to determine whether the drained system is safe or is still in danger from electrolysis.

In future installations of underground piping systems in the neighborhood of electric railways, precautions should be taken to minimize the flow of stray current to the pipes. To this end, the pipes should be laid as far from the electric railway tracks as practicable. Metallic contacts with the tracks, such as may exist at the iron gate boxes used in water piping systems, must be carefully avoided. Where the pipes cross steel bridges carrying electric railway tracks in metallic contact with the bridge structure, the pipes should be supported on wooden blocks or otherwise insulated from the metal of the bridge structure. Insulating

joints should be installed at the entrance of pipes to car barns, as it is frequently found that the pipes inside of the barns are in metallic contact with the tracks through the building structure. In special cases of individual pipe lines, insulating joints and, in some cases, also insulating covering of adequate thickness, may be employed in localized sections where conditions are found to be suited to their installation.

Remedial Measures Applied to Electric Railways.

The only way to entirely prevent electrolysis from stray railway currents is to prevent leakage of currents to earth from electric railway systems by the use of a separate and completely insulated return conductor, instead of using the running tracks as part of the return circuit. This is accomplished with the double underground trolley system, in use on the surface lines on Manhattan Island and in the central district of Washington, D. C., and with the double overhead trolley system, in use on the surface lines in Cincinnati, Ohio, and on some of the outlying surface lines in Washington, D. C., and in Seattle, Wash. These systems, while entirely effective in preventing electrolysis, have, however, not been generally adopted, probably because of the added expense and of the added complication involved over the ordinary single-trolley system, which latter has come into practically universal use.

To change a single trolley to a double-trolley system would involve a more or less complete change in system. While leakage of current from single-trolley electric railways cannot be entirely prevented by any methods that can be applied to these railways, the amount of stray current produced by a single-trolley railway can by adequate measures be reduced to any desired minimum values. As already shown, the direct cause of stray currents from electric railways is voltage drop in the running tracks. It is, therefore, clear that, by reducing this voltage drop, the stray currents leaking from such tracks will be correspondingly reduced. Since stray currents must flow from the tracks to earth, the amount of stray current produced by a given voltage drop is also dependent upon the resistance between the tracks and earth. The

leakage of currents from the tracks can, therefore, be likewise reduced by increasing the resistance between the tracks and earth. The reduction of stray currents through earth can best be accomplished by the following means, given in the order of their importance:

(1) By increasing the number of direct-current supply stations in systems extending over large areas, so as to reduce the radius to which any one station supplies current, and also by supplying all of the railways in any locality from one supply station in this locality. The increase in the number of supply stations has been brought about in several American cities through the unification of electric light and electric railway interests, whereby the joint utilization of electric light and railway substations for the supply of the railways has been made possible.

(2) By increasing the electrical conductance of the tracks, through the use of heavy rails, through the use of low-resistance rail joint bonds and cross bonds, and through the interconnection of the electric railway tracks of all systems, where these come close together.

(3) By removing current from the tracks by insulated return feeders, and by maintaining the negative bus-bar insulated from ground at the supply station, in all cases where the voltage drop in the tracks would otherwise be excessive. This arrangement is known as the *insulated track feeder system*, or the *insulated return feeder system.*

(4) By increasing the resistance between tracks and earth as much as practicable, through draining the roadbed and, on private right-of-way, through maintaining the rails out of contact with earth.

Where a road operates on a private right-of-way, the rails can often be practically insulated from ground and the escape of current from the tracks prevented. For surface roads this can be accomplished by placing the rails on wooden ties above ground and using broken stone for ballast and keeping the rails out of contact with ground. In the case of railway lines operating on elevated structures, the rails can be fastened to wooden ties and kept out of contact with the structures. These rails, supplemented where necessary with negative feeder cables, also insulated from

the structure, can then be used for the return conductor. In this way the return circuit is quite thoroughly insulated from the elevated structure and from earth, and stray currents are entirely prevented.

It has been proposed to employ a 3-wire system for distributing current to an electric railway. In this system pairs of generators in the power station are connected in series, and the junction point between the two generators is connected to a neutral bus-bar. The trolley line is divided into sections, and half of the sections are connected to the positive side of the generators and the other half to the negative side. The tracks become the neutral conductor and are connected to the neutral bus-bar at the power station. With this arrangement current flows in the tracks between the positive and negative line sections. The current flowing in the connection between tracks and the neutral bus-bar at the station is the difference between the current used on the positive and negative lines, and is therefore a relatively small current. This current also reverses more or less continually in direction, owing to the continually shifting loads, so that the polarity of the tracks with reference to underground structures at the power station also reverses more or less continually. With this arrangement the concentrated positive zone, usually present in the neighborhood of the power station, is removed, and there is in the neighborhood of the power station a low reversing potential condition. Current flowing in the tracks between the positive and negative sections is also relatively small compared with the current returned by the tracks with the usual arrangement of 2-wire system, so that the practical effect of the 3-wire system is to very greatly reduce the track voltage drop and correspondingly reduce the total amount of corrosion from electrolysis. In addition to this, the remaining corrosion from electrolysis is distributed over widely scattered areas. The 3-wire system has been in use to some extent in Europe, and experimental 3-wire installations are now in operation in two American cities.

The insulated track feeder system, in conjunction with proper track bonding, usually affords the most feasible means for reducing track voltage drop and thereby reducing stray currents through earth in an existing electric railway. In this system, feeders in-

sulated from earth are connected from the negative bus-bar to selected points on the track network.

Diagrammatic sketches illustrating the negative connections of an electric railway with and without the insulated return feeder system are shown in Fig. 4. In this figure the railway lines are assumed radiating out from the power station. In the left-hand diagram the rails of these lines are shown connected to the negative bus-bar at the power station only. It is seen that, as the result of this, all of the current used on the eight railway lines flows toward the power station in the rails. The stray currents which leak from the rails to earth also concentrate in earth and on the underground piping in the neighborhood of the railway power

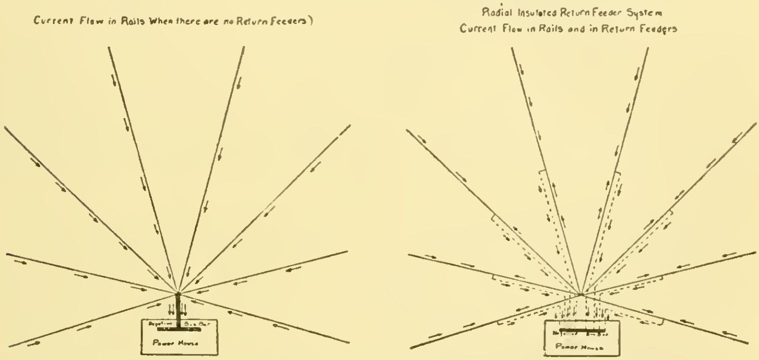


Fig. 4. Diagrams showing Trolley Lines Radiating out from Power Station with and without Insulated Return Feeders, and showing Path of Return Currents.

station, where they must return to the rails to get back to the negative bus-bar.

If this connection between the negative bus-bar and the rails at the power station is removed, and the currents collected from the rails at points near the center of each railway line by means of insulated track feeders, as shown in the right-hand diagram of Fig. 4, the concentration of current in the neighborhood of the power station is entirely removed. With this arrangement the current used by each individual line tends to flow away from the rails at both ends of this line, and toward the rails near the center

of the line. It is therefore seen that only one eighth of the current is collected from the rails at any one point that there is when the rails are connected to the negative bus-bar only at the power station. Further, assuming similar soil conditions, the total stray current through earth with the conditions shown in the right-hand diagram will be only one fourth of the total stray current with the conditions of the left-hand diagram, so that at any one point, the danger from electrolysis will be one thirty-second of what it is in the neighborhood of the power station with the first arrangement. As a matter of practice, however, the actual reduction is very much greater, because the track feeder connection-points to the rails can be chosen so as to be located where the ground is high and dry, and consequently of high resistance, whereas the railway power station is generally located near water, where the ground is wet and of low resistance. Instead of connecting one insulated track feeder to the middle point of every line, as indicated in the figure, a number of such feeders may be connected to a number of properly selected points in every line. In this way the drop in the rails and consequently also the stray current produced can be reduced to any desired low value.

The diagrams of Fig. 5 illustrate the possibilities in the way of reducing stray currents by means of properly proportioned insulated return feeders. They are taken from a paper presented a few years ago by Mr. George I. Rhodes, who was at that time in the employ of the Interborough Rapid Transit Company of New York City. This company installed a system of insulated track feeders in connection with its subway systems in New York City. The diagrams in Fig. 5 illustrate the relative amounts of leakage current with various connections from the tracks to the negative bus-bar of the power station. It will be seen that with the negative bus-bar grounded through a connection of negligible resistance, in addition to being connected to the rails at the power station, the greatest amount of stray current is produced, which is assumed unity for the purpose of comparison. This is illustrated by Diagram A of Fig. 5. Disconnecting the negative bus-bar from earth at the station, but not from rails, reduces stray currents to one fifth of their former value, as illustrated by Diagram B of Fig. 5. Disconnecting the negative bus-bar from earth

and from the rails at the power station, and returning the current by means of one insulated track feeder from the center of the line, reduces stray currents to 5 per cent. of their former value, as illustrated by Diagram C of Fig. 5. By using two insulated track feeders, with the negative bus-bar insulated, the stray currents are reduced to 1.2 per cent. of their former value, as illustrated by Diagram D of Fig. 5. It will therefore be seen that very great reduction of stray currents can be accomplished by insulating the negative bus-bar at the power station from earth and from rails, and returning the current by means of insulated track feeders.

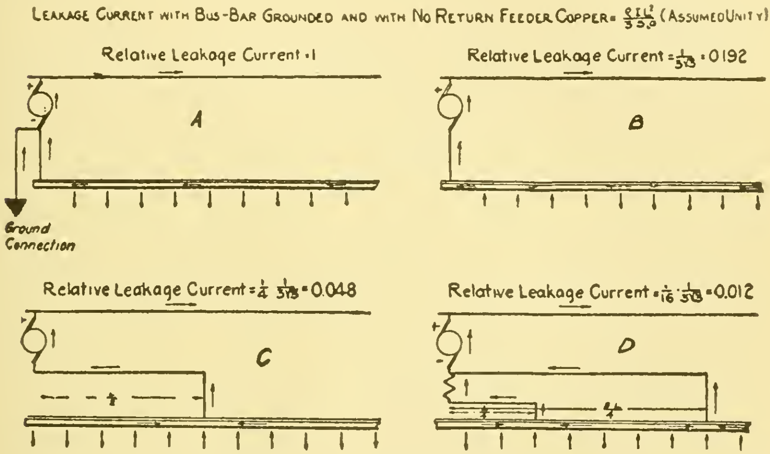


FIG. 5. RELATIVE LEAKAGE CURRENTS WITH VARIOUS RETURN-CIRCUIT CONDITIONS.

The insulated track feeder system is frequently confused with the system of *paralleling the tracks* with return feeders, which has been most commonly used in American electric railways. From the standpoint of reducing track voltage drop, the two systems are, however, totally different. With copper feeders paralleling the tracks, the voltage drop in the tracks is reduced only in the proportion that the conductance of the track circuit is increased. For example, an amount of paralleling copper equal in conductance to the tracks could at best only reduce the drop in these tracks to one half. It is therefore evident that, where the voltage drop in

tracks is high, this system would require a prohibitive amount of copper to reduce the voltage drop to reasonably low values. With the insulated track feeder system, on the other hand, the voltage drop in the insulated feeders does not occur in the tracks nor in the earth, and therefore may be made as high as economy dictates. It should be emphasized that with insulated feeders, the tracks in the immediate neighborhood of the power supply station should be connected to the negative bus-bar only through a suitable resistance, since a direct connection at this point would practically convert the insulated feeder system into a system of feeders paralleling the tracks, because both ends would then be in contact with earth.

I have recently had the opportunity of studying the results obtained with an insulated track feeder system in a city of moderate size, in which the direct-current railway substation is located on one side of a river. On the opposite side of this river there is located the city pumping station, and in the grounds near this station there are a large number of well pipes which furnish the city water supply. When I first made tests in this city, a great deal of trouble had been experienced from electrolysis, particularly of the well pipes and suction mains connected to them. The reason for this was that the negative bus-bar in the substation was connected to the tracks directly at the station, and there were no return feeders carried beyond the station, so that all of the current used by the railway system was obliged to return through the tracks and earth. As a result of this construction, a large amount of stray current reached the water piping system throughout the city, flowed toward the railway substation and then left the water pipes to return to the railway return circuit. As a matter of fact, the water pipes entering the pumping station grounds carried a total average current of from 50 to 100 amperes, which left the water piping in the pumping station grounds, and thereby caused the destruction of this piping by electrolysis. In order to remedy these conditions, the railway company repaired all defective track bonding and installed an insulated return feeder system. Insulated feeders, in some cases with resistors in series, were carried from the substation to four points in the track network located at some distance from the station, and the connec-

tion from the tracks to the negative bus-bar at the substation was made through a resistor so proportioned that the tracks in the neighborhood of the substation would not be the point of lowest potential in the track system. After the track feeder resistors had been finally adjusted, there was not a single location at which the pipes were at all times positive in potential to the tracks, and even in the neighborhood of track feeder connection points there was a low voltage of continually reversing polarity, averaging less than one volt. At other locations the water pipes also reversed continually in polarity, or were at all times negative to the tracks.

A comparison of the currents found on the water mains before the railway improvements had been made, and after these were completed, show that the reduction in these currents is very great. For example: A current of 27 amperes was reduced to 1.3 amperes; a current of 33 amperes to 2.4 amperes; a current of 8 amperes to 0.5 ampere; a current of 8 amperes to 0.07 ampere; a current of 18 amperes to 0.6 ampere; and a current of 3.7 amperes to 0.9 ampere. In addition to the large reduction in the amount of current on the water pipes, the remaining relatively small currents reversed more or less continually in direction, whereas the former large currents all flowed in one direction, namely, towards the pumping station grounds. The reduction in electrolysis troubles in this city is therefore very much greater than expressed by the reduction of currents on the water mains, and, in fact, with the continually reversing currents and potentials there should now be little if any trouble. I believe that reference to these results is the best illustration that I can give you of the effectiveness of improvements in the railway return circuit in reducing electrolysis troubles from stray currents due to single-trolley electric railways.

There are invested to-day in this country hundreds of millions of dollars in single-trolley electric railways which operate under franchises permitting them to use this method of operation. The use of the insulated track feeder system is a plan which can be adopted by such single-trolley railways for the purpose of minimizing electrolysis troubles without requiring a change in the system of operation, and at a cost which is well within practical

limits. It should be stated, however, that with the insulated track feeder system the power losses are increased over what they would be if the same amount of copper were employed in parallel with the tracks. This increase in power losses is a necessary and legitimate expense, incurred for the purpose of reducing stray currents through earth and correspondingly reducing injury to underground structures.

Summary.

Experience shows that an increasing amount of damage by electrolysis is occurring on underground piping systems in many localities throughout the country where adequate measures have not been taken to reduce this damage. The principal and generally the sole sources of stray electric currents causing this damage are the single-trolley direct-current electric railways employing the running tracks in contact with earth as part of the return circuit. Experience extending over many years in foreign countries and over ten years in this country has shown that practicable and economical methods of construction can be applied to such electric railway systems which will remove acute dangers from stray currents to underground piping systems and which will greatly reduce the electrolysis danger in all cases, and in most cases will make this danger negligible. Mitigating methods applied to underground pipes fail to attack the source of the trouble and should be applied only in special cases, if at all, and then only after adequate methods of minimizing the production of stray currents have been applied to the railway system. Metallic connections from underground water pipes to the railway return circuit which cause these pipes to become a substantial part of this return circuit are inadequate for the protection of the pipes, and are frequently dangerous. Such connections greatly increase current flow on pipes, and, while they may afford local protection, they generally distribute electrolysis troubles to other localities where they are more difficult to find, and in this way frequently give a false impression of immunity. Metallic connections from water pipes to the railway return circuit should generally not be permitted and in no case unless a careful study of conditions has shown that no serious danger will be produced. Such connections

should never be applied to an underground piping system as the principal means of electrolysis mitigation.

In view of the fact that the railway companies in common with the pipe-owing companies are public utilities operating under public franchises and utilizing city streets, it is the duty of both of these utilities to coöperate in order that the causes and extent of any danger from stray currents can be more readily ascertained. Further, the satisfactory solution of the electrolysis problem is one which requires the coöperation of all of the interests concerned. I think that in the past the red flag has been waved too much, and some owners of underground properties have made unreasonable demands, with the result that the electric railway companies have been afraid to coöperate for fear that they would be asked to make excessive expenditures. There is no real reason for this. Electrolysis is an engineering problem, and can be handled by engineering methods in such a manner that no hardship need be imposed nor should be imposed on any one. There is no reason why the negative feeder system should not be laid out along the same engineering lines as the positive feeder system. I think that if the electric railway companies would realize this and the owners of underground properties would coöperate in a practical way, we could obtain a satisfactory and practical solution of the electrolysis problem. For instance, it often happens that the judicious installation of a few insulating joints will save a lot of money in railway track feeders, and in such cases such joints should be installed.

A most important step towards securing the coöperation, which is absolutely necessary in order to obtain adequate and permanent relief from electrolysis, has been made by the formation of the American Committee on Electrolysis. This committee includes representatives of the electric railway, water, gas, electric light, and telephone interests. This committee was organized in 1913 and has completed a preliminary report setting forth the facts regarding electrolysis, upon which the representatives of all of the varied interests have agreed. The committee has already accomplished a great deal towards producing a closer coöperation between the interests owning the electric railways and those owning the underground structures, and it is to be hoped that the

future work of this committee will result in the unanimous adoption of recommendations which will reasonably safeguard underground piping systems against electrolysis.

Discussion.

Mr. William F. Sullivan.* I would like to ask Professor Ganz what is the danger, if any, of connecting transformer secondaries to service pipes?

Professor Ganz. Ordinarily, there is no danger in connecting transformer secondaries to water pipes, and I have generally recommended it.

Mr. George Cassell.† I would like to know what would be the result of grounding cables from the transformers to water mains instead of house service pipes, providing anything happened to cause current to pass over that line to the main.

Professor Ganz. There ought not to be any material difference between grounding a transformer secondary to a service pipe, or grounding it to a main. It sometimes happens that a service pipe makes a rather high resistance contact with the main, but that is rare. On the other hand, a connection to a service pipe can be readily inspected, whereas in the case of a main, an examination cannot be made.

Mr. Cassell. I remember my first experience was in trying to stop electrolysis on a service pipe that went underneath the rails, and I attempted to dissipate it by putting a rubber jacket over the pipe; but I very soon found I was merely driving it from one place to another, so I quit.

Mr. Morris Knowles.‡ Regarding the grounding of the generating system of a telephone company in their own exchange building. Does that come under a different class?

Professor Ganz. I do not believe that there is any danger connected with that. It is merely a circuit for ringing bells, and the currents used for that purpose are so small compared with those used in electric railway circuits that they are negligible.

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.
† Commissioner of Water Works, Chelsea, Mass.
‡ Consulting Engineer, Pittsburgh, Pa.

Mr. G. A. Caldwell. A lead joint sometimes acts practically as an insulating joint, or becomes so through the lead or jute keeping the bell and spigot ends of the pipe apart.

What would be the effect of bonding one pipe to the other with copper wire, and carrying the electricity along the line until you wished to take it from the pipe, and not allowing it to leave one section of the pipe until it had arrived at the point where you wished to have it leave?

Professor Ganz. If you could connect across every joint of a piping system with a heavy copper wire, and be sure that good contact was maintained, and if there were no other underground pipes or cable systems in the neighborhood, it would be possible to safeguard that particular piping system. But those conditions do not exist in practice. We have to deal with a variety of neighboring underground structures, and we must not make one piping system a serious source of danger to other underground systems.

Mr. Caldwell. Would the fact that the cast-iron pipe was carrying water make it a better conductor than a wrought-iron pipe?

Professor Ganz. The resistivity of water is so great compared with that of iron that it would have no appreciable effect on the resistance of the pipe.

Mr. Patrick Gear.* The only trouble we have had from electrolysis is that the insurance companies penalize us because we haven't made an examination or a survey. We never have had any trouble with electrolysis, that I know of. Some years ago I had a break in a pipe about three miles from a railroad of any kind, and the man who was fixing the pipe got a shock, and we thought for a while he was gone. I wondered what the trouble was, and they said it was electrolysis, but I don't know where it could have come from. The place was three miles away from a railway.

Professor Ganz. In a survey which I made, this past summer, on a pipe line several hundred miles long, we found stray electric currents at points on the pipe many miles distant from any electric railway. I have found similar conditions on many other pipe lines.

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* Superintendent of Water Works, Holyoke, Mass.

Mr. Frank L. Fuller.* At Wellesley we have two trolley systems which cross each other in one of the villages, and for more or less distance the rails are over the main pipes, and, of course, cross a good many service pipes; but we have never had any trouble from electrolysis. Those roads must have been running, one of them for fifteen or eighteen years, and the other one, perhaps, for ten years.

At Marblehead, about two years ago, there was a 10-in. pipe, which must have been, I should say, 2 000 ft. from the nearest trolley line, where there was trouble which was thought to come from electrolysis. The pipe, I believe, passed through some rather boggy, low land, and it is possible that the trouble came from that. The general opinion was that the trouble was due to electrolysis. They also have a good deal of pipe that is very much nearer to the railroad tracks than this particular pipe to which I have referred. I suppose this trouble might have been from electrolysis, although the car line is so far away.

Professor Ganz. Yes. One of the pipe lines I spoke of before crossed a number of trolley tracks, but the worst corrosion occurred not under any of the tracks, but in a field at least one thousand feet away from the tracks. This was undoubtedly due to the fact that the ground in this field was wetter and more acid on account of the refuse from farm animals. It should be emphasized that whatever soil conditions are conducive to chemical corrosion are also conducive to electrolysis.

I would like to ask the gentleman whether the water mains he spoke of were laid before the trolley tracks were laid.

Mr. Fuller. Yes.

Professor Ganz. I have found a number of cases where mains had been laid a number of years before there was any trolley service, and where these mains became coated with oxide which later appeared to protect them when the trolley system started operation. I have one case in mind, where there were some old cast-iron mains, probably fifty years old, in localities where new pipe was corroded very rapidly by electrolysis, while these old mains were not affected.

Mr. Fuller. I should like to say, in addition, that of course

* Civil Engineer, Boston, Mass.

we have laid a good many pipes since the installation of the electric roads, and there has been no trouble with those either.

PROFESSOR GANZ. They are probably connected with the old mains, are they not?

MR. FULLER. Yes, they are.

PROFESSOR GANZ. If the greater part of the network was of old pipe, the oxide coating would tend to prevent these mains from gathering stray current, and in this way would help protect the new pipe.

A MEMBER. I wonder whether you would care to express an opinion as to the advisability of making a survey, in a city, of a water-works system.

PROFESSOR GANZ. It is always advisable, because until you do make a survey you have no idea what the conditions are; and, if you have trouble, and quick repairs are made, you cannot tell whether the trouble was due to electrolysis or not. Furthermore, my experience has been that when the railway companies know that the water and gas interests are making surveys of their systems and finding out what the stray current conditions are, they will of their own accord take greater care of their return systems.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, Mass., March 14, 1917.

The President, Mr. Caleb M. Saville, in the chair.
The following members and guests were present:

Honorary Members.

E. C. Brooks. A. S. Glover. F. E. Hall. R. J. Thomas. — 4.

Members.

L. M. Bancroft.
F. A. Barbour.
G. H. Bean.
C. S. Beaudry.
A. E. Blackmer.
J. W. Blackmer.
George Bowers.
Bertram Brewer.
Geo. A. Carpenter.
George Cassell.
J. C. Chase.
H. W. Clark.
F. L. Cole.
J. E. Conley.
John Cullen.
W. R. Edwards.
E. D. Eldredge.
R. H. Ellis.
G. F. Evans.
S. F. Ferguson.
F. L. Fuller.
Patrick Gear.
H. T. Gidley.
F. J. Gifford.
J. A. Gould.
C. R. Gow.
R. K. Hale.
H. A. Hanscom.
A. R. Hathaway.
D. A. Heffernan.
C. R. Hildred.
W. F. Howland.
W. F. Hunt.
C. E. Johnson.
G. A. Johnson.
W. S. Johnson.
J. W. Kay.
E. W. Kent.
Willard Kent.
Patrick Kieran.
S. E. Killam.
John Knickerbacker.
Morris Knowles.
P. J. Lucey.
W. F. Lumbert.
Thomas McKenzie.
W. A. McKenzie.
H. V. Macksey.
W. E. Maybury.
John Mayo.
F. E. Merrill.
G. F. Merrill.
H. A. Miller.
E. E. Minor.
William Naylor.
T. A. Pierce.
A. E. Pickup.
H. G. Pillsbury.
C. L. Rice.
L. C. Robinson.
J. A. Rourke.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
C. W. Sherman.
G. H. Snell.
O. H. Starkweather.
W. F. Sullivan.
H. A. Symonds.
Milton Thorne.
C. H. Tuttle.
W. H. Vaughn.
R. S. Weston.
L. J. Wilber.
F. B. Wilkins.
G. E. Winslow.
I. S. Wood. — 78.

ASSOCIATES.

Harold L. Bond Co., F. M. Bates, G. S. Hodge.
Builders Iron Foundry, A. B. Coulters, G. H. Lewis, F. N. Connet.
A. M. Byers Co., H. F. Fiske.
Chicago Pneumatic Tool Co., F. S. Eggleston, Jr.
Darling Pump & Mfg. Co., H. A. Snyder.
Eddy Valve Co., H. R. Prescott.
Hersey Mfg. Co., J. H. Smith.
The Leadite Co., George McKay, Jr.
Lead Lined Iron Pipe Co., T. W. Dwyer.
H. Mueller Mfg. Co., G. A. Caldwell.
National Meter Co., H. L. Weston.
National Water Main Cleaning Co., B. B. Hodgman.
Neptune Meter Co., H. H. Kinsey.
Pittsburgh Meter Co., J. W. Turner.
A. P. Smith Mfg. Co., F. L. Northrop.
Thomson Meter Co., E. M. Shedd.
Water Works Equipment Co., W. H. Van Winkle.
Worthington Pump & Machinery Corporation, W. F. Bird, Samuel Harrison, E. P. Howard. — 23.

GUESTS.

NEW HAMPSHIRE.

Concord, H. A. Rowell, engineer.

MASSACHUSETTS.

Boston, C. DeWitt Jarvis, engineer outside plant, N. E. Tel. & Tel. Co.; William Spence; W. I. Towne, engineer electrolysis.
Lowell, G. H. Brown, water commissioner.
Manchester, G. E. Hildreth, commissioner.
Natick, William Leahy, superintendent water works.
Norwood, J. J. Drummey, commissioner.

RHODE ISLAND.

East Greenwich, James Kinloch.
Newport, G. N. Buckhout.

NEW YORK.

Woodhaven, J. A. Cochran.

PENNSYLVANIA.

Pittsburgh, G. F. Magloth. — 12.

The Secretary read the following names of applicants for membership, the applications having been properly endorsed and recommended by the Executive Committee:

Active — Harold S. Crocker, Brockton, Mass., city engineer; E. Drinkwater, St. Lambert, P. Q., Canada, consulting and designing engineer; A. J. Mahnken, civil engineer, Weehawken, N. J.; John D. Points, Palatka, Fla., superintendent Palatka Water Works.

Associate — Edson Manufacturing Company, Boston, manu-

facturers of gasolene engines, diaphragm pumps, suction hose, and pump material.

On motion of Mr. Frank L. Fuller, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

The President announced that the Executive Committee had decided on Hartford, Conn., as the place for the annual convention, to be held in the week beginning September 10.

Mr. William S. Johnson, sanitary and hydraulic engineer, Boston, Mass., presented a paper entitled "Statistics Relating to the New England Water Works Association."

Albert F. Ganz, M.E., professor electrical engineering, Stevens Institute of Technology, and consulting engineer, Hoboken, N. J., spoke on "Electrolysis — Troubles Caused thereby and the Remedies which may be Applied." Mr. George Cassell, Mr. William F. Sullivan, Mr. G. A. Caldwell, Mr. Patrick Gear, Mr. Frank L. Fuller, and others took part in the discussion which followed; and, on motion of Mr. Cassell, a rising vote of thanks was given Professor Ganz.

Mr. William S. Johnson, for the Committee on Service Pipes, submitted the final report of the committee. On motion of Mr. Frank L. Fuller, the report was accepted and the committee discharged.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., March 7, 1917.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Willard Kent, Richard K. Hale, Lewis M. Bancroft, and George A. King, and, by invitation, William S. Johnson and William F. Woodburn.

On motion of Mr. Killam, it was voted: That a committee of three be appointed by the President to consider the subject of meetings.

Voted: That a committee of three be appointed by the President to take measures to increase the membership.

On motion of Mr. Killam, seconded by Mr. Bancroft, it was voted: That a committee of three be appointed by the President to investigate and report at the next meeting of the Executive Committee as to the most desirable place for holding the next annual convention, the expense of said committee to be paid by the Association.

On motion of Mr. King, it was voted: That the details of arrangements for the annual convention be referred to a Committee of Arrangements to be hereafter appointed.

President Saville subsequently appointed as a Committee on Membership, Samuel E. Killam, Percy R. Sanders, and Henry B. Machen.

Committee to investigate and report on most desirable place for next annual convention, William F. Woodburn, William S. Johnson, and Frank J. Gifford.

Mr. Charles E. Coyne, Secretary of Chamber of Commerce of Holyoke, Mass., and Mr. Mandel Sener, Manager of Publicity Bureau of Hartford, Conn., appeared before the committee and spoke of the hotel accommodations to be had in the cities they represented.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Wednesday, March 14, at 11 o'clock A.M.

Present: President Caleb M. Saville, and members Samuel E. Killam, Frank A. Barbour, Thomas McKenzie, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Richard K. Hale, H. V. Macksey, Lewis M. Bancroft, Willard Kent, and, by invitation, William S. Johnson and Charles W. Sherman.

Four applications for active membership and one for associate were received and they were by unanimous vote recommended therefor:

Harold S. Crocker, city engineer, Brockton, Mass.; Ernest Drinkwater, municipal engineer, St. Lambert, P. Q., Canada; A. J. Mahnken, C.E., Weehawken, N. J.; John D. Points, superintendent water works, Palatka, Fla.

Associate: Edson Manufacturing Company, Boston, Mass.

A letter from Mr. F. H. Newell, Secretary of the Association for Engineering Coöperation, asking that a delegate be appointed to the next meeting of that association, was read, and Mr. John W. Alvord was, by vote, made the representative of this Association for that purpose.

Mr. Frank J. Gifford, of the committee appointed to investigate the accommodations to be had in different cities for the next annual convention, reported in favor of Hartford, Conn. The report of said committee was, by unanimous vote, accepted.

On motion of Mr. Killam it was voted: That the next Annual Convention of the New England Water Works Association be held at Hartford, Conn., during the week beginning September 9, 1917, the number of days' duration to be at the discretion of the Committee of Arrangements to be hereafter appointed.

On motion of Mr. Killam, it was voted: That the President appoint a committee of five who, with the President, Secretary, and Treasurer, are to constitute a Committee of Arrangements for the next Annual Convention.

The President subsequently appointed the following committee; William S. Johnson, Henry V. Macksey, Samuel E. Killam, Charles W. Sherman, Henry R. Buck, President Saville, Secretary Kent, and Treasurer Bancroft to be members *ex officio*.

Adjourned. Attest: WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., May 2, 1917.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Richard K. Hale, Lewis M. Bancroft, George A. King, Willard Kent; also W. S. Johnson and C. W. Sherman of the Committee of Arrangements for the Annual Convention.

Editor Hale tendered his resignation on account of his military duties.

On motion of Mr. Macksey, the following resolution was unanimously adopted.

Resolved: That the resignation of Major Hale, by reason of his being called to military duty, be and hereby is accepted, to take effect at such time as he leaves for active service, with full appreciation of the able and satisfactory manner in which he has performed the duties of Editor, and the hope that he may soon return to resume those duties.

Mr. William S. Johnson was unanimously elected Editor of the Association to fill the vacancy caused by Mr. Hale's resignation.

The question of omitting the June outing and the Annual Convention of the Association on account of the declaration of war was discussed and decided in the negative.

On motion of Mr. Macksey it was voted: That the Committee on June Outing be instructed to confer with the Committee of the Boston Society of Civil Engineers with reference to a joint meeting; if such is found undesirable, the committee is to arrange, should they deem it advisable, for a meeting at which papers may be presented or discussion had on the subject of "War Measures for Protection of Water Supplies."

Voted: That Mr. W. S. Johnson be and hereby is made a committee, duly authorized and with full power, to transfer to the Boston Society of Civil Engineers the pamphlets now occupying the bookcase recently purchased by them, reserving only such as may in his judgment be of special value to members of this Association.

The report of Mr. John W. Alvord, delegate of this Association to the Chicago Conference on Engineering Coöperation, was read, accepted, and ordered placed on file.

The subject of the recent death of Mr. Albert S. Glover, honorary member of this Association, was introduced by Mr. Macksey, and remarks were made by the members present expressing their own grief and feeling of personal loss, their recognition of the loss sustained by the Association, and their appreciation of his unfailing devotion to its interests.

Mr. Macksey then presented a resolution on the death of Mr. Glover, which was unanimously adopted.*

Messrs. R. C. P. Coggeshall, Charles W. Sherman, and J. C. Whitney were, by vote, constituted a committee to prepare a memoir of the late Mr. Albert S. Glover for publication in the JOURNAL of the Association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

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* The resolution will be found on page 321.

ALBERT SEWARD GLOVER.

Charter, Active and Honorary Member of the New England Water Works Association.

Born April 6, 1855. Died April 23, 1917.

Albert S. Glover was born at South Boston on the date noted above. His father was Albert Henry Glover, originally of Ipswich, Mass., and his mother was Mary Ann Wilson, of Salem. His parents moved to Cottage Farm when he was a young boy, and to West Newton in 1864. For many years Mr. Glover's father was master builder for the Boston & Albany Railroad, having charge of the construction of various wooden bridges and buildings, some of them very large.

Albert S. Glover attended the Newton High School, where he was a leader in athletics, particularly in baseball and football. He was graduated in 1873, being a classmate of John A. Gould. In the fall of that year he entered the Massachusetts Institute of Technology with the class of 1877, having as classmates Prof. George F. Swain, Richard A. Hale, Henry H. Carter, Joseph P. Gray, Charles F. Lawton, George W. Kittredge, the late E. H. Gowing, and other well-known engineers.

In 1875, when work on the Sudbury Water Works for the City of Boston was actively begun, Mr. Glover left the Institute and took a position on the engineering force, being associated with Frederic P. Stearns, George S. Rice, Wilbur F. Learned, and others. A little later he was assigned by the engineer, Mr. Alphonse Fteley, to act as his secretary, and as assistant to the paymaster and purchasing agent; and in 1879 he became paymaster and purchasing agent. In July, 1879, he was elected water registrar of the City of Newton — the executive officer of the Water Department — and held that position until January 1, 1890, when he resigned to become secretary of the Hersey Manufacturing Company, having charge of sales of Hersey meters in New England. To this work he devoted the remainder of his life. He was also clerk of the Common Council of Newton from 1882 to 1887.

Mr. Glover was married, on September 21, 1875, to Mary Wales Robinson, of Newton, who survives him, with their daughter, Mary Wales Glover, a graduate of Smith College.

He was a member of the following societies and clubs, in addition to the New England Water Works Association: American Water Works Association, Boston Society of Civil Engineers, Newton Club, Boston City Club, Engineers Club, Hunnewell Club, Middlesex Club, Economic Club, Bostonian Society, Brae Burn Country Club, Tedesco Country Club.

His activities with this Association are of particular interest to us. His deep concern in its affairs covers the entire range of its existence. Prominent in its organization, on July 21, 1882, he remained an active member until February 10, 1915, when he was named an honorary member. His death reduces the number of living charter members to three. Mr. Glover possessed a well-ordered mind and was recognized as a skillful organizer and leader. He had a decided talent in naming the right man to to take charge of special investigations.

He was Secretary of this Society, 1884–87; Treasurer, 1887–89; Editor, 1884–86, and Junior Editor, 1889–91. His early activities resulted in inducing a large number of the better-known water officials throughout the country to join the Association, and during the existence of the organization he has probably influenced more to become members than has any other member.

The scheme of presenting the transactions of this Asssociation in the form of a quarterly publication was first conceived and suggested by Mr. Glover in 1886, when he then outlined the plan in detail, which included the addition of an up-to-date index from time to time. The JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION is the result; and every member will testify to the value of the index.

His interest and enthusiasm has never faltered. From soon after his connection with the Hersey Manufacturing Company, he declined all official connections, but he continued to be a silent, influential worker. He was probably the best-informed member as regards incidents, happenings, and procedure in past meetings; and was also an authority in parliamentary rules and methods. He was such a walking encyclopedia in these matters that he was

ALBERT S. GLOVER.

Charter Member N. E. W. W. A., June 21, 1882.

Honorary Member, February 10, 1915.

constantly sought by the numerous committees for information and counsel.

The Executive Committee of this Association has expressed its sense of the loss suffered by the Association and its members in the following resolution:

Whereas, since last the Executive Committee of the New England Water Works Association met there has passed away one of the charter members of the Association, and feeling our great loss as we do, we cannot allow this meeting to close without placing upon record some expression of the sorrow which oppresses us;

Therefore be it resolved, that this committee realizes that when death came to Albert S. Glover, our Association lost one of its most valuable members. The committee also realizes that each of its members has lost a true friend, one who was always ready to advise and assist when needed.

His record for sterling integrity, his high standard of honor, and his absolute fairness in all his business affairs have elevated the standard of the water-works business in New England, and is an inspiration to all who have had the good fortune to be associated with him.

The memory of his many good deeds will remain with us through all the years.

Be it further resolved, that the committee wishes to convey its most heartfelt sympathy to his family, and that the President be instructed to send to Mrs. Glover a copy of these resolutions.

Mr. Glover possessed a very sympathetic as well as a very sensitive nature. The generosity of his sympathy to his friends who were in trouble was well known, and a quiet talk with " Bert " was sure to leave the friends more buoyant with the perfume of good cheer, in a way that held them to him with " hooks of steel " and rendered him their helper, comforter, and friend.

Your committee have taken up this study with heavy hearts. It is indeed sad to realize that a spirit, so brave, cheery, and sunny, is to be with us no more. We keenly realize that the Association has lost one of its most trusted and faithful workers, and that each of us has lost a loyal and true friend.

R. C. P. Coggeshall,
Charles W. Sherman,
John C. Whitney,
Committee.

New England Water Works Association.
ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

REPORT OF COMMITTEE ON SERVICE PIPES.

[*Presented March 14, 1917.*]

To the New England Water Works Association:

Your Committee on Service Pipes begs to submit the following report:

The requisites for a good service pipe are, in order of their importance, (1) that it should not affect the water passing through it in such a manner as to make it injurious to the health of those using the water; (2) that it should not have a deleterious effect on the appearance, taste, or odor of the water even though not injurious to the health; (3) that it should have a sufficient capacity to give adequate service at all times; (4) that it should be strong and durable; (5) that it should be easily laid; (6) that it should be inexpensive.

To meet the first condition, that portion of the service pipe which comes in contact with the water should be of some material which is either not acted upon by the water standing in contact with it, or, if acted upon, produces no compounds which would affect the health of those using the water.

To meet the second condition, the material of which the inside of the service pipe is composed should not be acted upon by the water to produce rust or other substances which may come away with the water; it should not be composed of any material which will disintegrate; it must not be coated with any substance which will impart a taste or odor to the water.

These first two conditions should be considered absolutely essential in any system, for, as Mr. FitzGerald so well expresses it

in his discussion, "of what use is it to spend millions and millions on the quality of your water and yet allow services which affect that quality materially?"

To carry a sufficient quantity of water for good service, the pipe should be of suitable size, dependent, to some extent, on the available pressure, and should not become coated on the inside with rust or other material so as to diminish the flow to such an extent as to make the service unsatisfactory. The requirements of the water takers as to the rate of use of water are ever increasing, and these requirements should be met.

Strength and durability should be assured chiefly as a matter of economy. Where services are laid in streets having expensive paving, the digging up of a service pipe is a serious matter. The service should, therefore, be constructed of material that will stand the pressure which may be put upon it, and will not be corroded by the action of the water on the inside or the action of the atmosphere, or of substances which may be contained in the soil on the outside.

It is desirable to have a flexible pipe which may be bent around any obstructions which are likely to be encountered in the street and one which is not liable to break with any settlement which may take place.

The first cost of the service pipe is the last point which should be considered, for it is a very small item as compared with the cost of maintenance and the cost of renewals. In fact, it may be said that the service pipes cost the least to install of any portion of the water-works system and are capable of giving the greatest amount of trouble.

The service pipe which perfectly meets all of the above conditions has not been put on the market, and after many years' experience water-works men are not yet agreed as to the materials which most nearly meet them. The committee has, however, secured as much information as possible both from men of practical experience and those who have approached the subject from a scientific standpoint.

The committee began its investigations by sending to every water department in New England, and to the members of our Association outside of New England, a request for information in

regard to the materials and methods used in service-pipe construction, the troubles experienced, and other matters which appeared to the committee to be of interest in this connection.

Replies were received from over three hundred water departments, many of them giving complete and valuable information. There were, however, many things which the committee felt should be further explained, and at two meetings of the committee a number of superintendents who appeared to have had exceptional opportunities to obtain valuable experience along lines which it seemed important to investigate were invited to be present, and each of these men was in turn questioned in regard to the details of his practice and experience.

The committee has also had the benefit of the discussions which took place at two meetings of the Association prior to the appointment of the committee and the discussion of the preliminary report of the committee at the convention in September, 1916.

In considering the information contained in the replies received from the three hundred and more water departments, it should be borne in mind that the returns from New England include a large number of small places. The returns from outside of New England are chiefly confined to larger places.

Materials Used for Service Pipes.

The returns in regard to the material now used for new services may be summarized in table on page 326.

The use of plain wrought iron or steel for new services is becoming rare, while nearly one half of the places sending in reports now use galvanized wrought iron or steel exclusively. Galvanized pipes are used either exclusively or in part in 56 per cent. of the places; lead or lead-lined pipes in 31 per cent.; and cement-lined in 16 per cent. It is noticeable that the use of cement-lined pipe is largely confined to Massachusetts and New Hampshire, forty-six of the forty-eight places using it being in these two states.

Of the new water-works systems — those constructed within the past ten years — the following materials have been used for services:

Galvanized	24	Lead	2
Plain wrought iron	1	Cement lined	9

Number of Water Departments using Service Pipes of Various Materials, as Reported to the Committee.

Material.	Me.	N. H.	Vt.	Mass.	R. I.	Conn.	N. Y.	Other States.	Total.
Plain wrought iron or steel	1	...	1	6	1	3	1	...	13
Galvanized	15	19	4	54	6	26	6	15	145
Lead	...	1	1	15	4	5	6	16	48
Lead lined	1	3	...	7	....	...	...	2	13
Cement lined	...	5	...	32	...	...	...	...	37
Galvanized and lead	...	...	...	7	...	2	...	5	14
Galvanized and cement lined	...	...	...	4	...	...	...	...	4
Galvanized, lead and cement lined	...	...	...	2	...	...	...	...	2
Galvanized and lead lined	2	...	...	4	1	1	1	1	10
Iron and cement lined	...	1	...	1	...	...	...	...	2
Cement lined and lead lined	...	....	...	1	...	...	...	...	1
Cement lined and lead	...	...	...	...	1	1	...	...	2
Lead and lead lined	...	...	...	3	...	...	1	...	4
Lead and wrought iron	...	...	...	...	...	2	1	...	3
Miscellaneous	...	...	1	3	...	1	...	1	6
	19	29	7	139	13	41	16	40	304

Changes Made in Material Used.

Many towns continue to use for service pipes the material which has always been used since the works were installed, although in many cases much trouble has been experienced. There are, however, about one hundred places where changes are reported to have been made for various reasons. A study of these changes and the reasons given therefor is very interesting.

The table on following page gives the changes which have been made and materials used before and after the change.

The disfavor with which plain iron and steel are regarded is shown by the fact that 22 places have changed from these materials to some other, while only one place has reported as having taken up their use. Galvanized pipe, on the other hand, has lost only 17 while gaining 46. Lead and lead-lined pipes have gained 18 and 16 places respectively and lost 6 and 8. Changes to cement-lined pipes have occurred in 11 places, and changes

Changes.

From	To: Wrought Iron or Steel.	Enameled.	Galvanized.	Lead.	Lead Lined.	Cement Lined.	Totals.
Wrought iron or steel	. . .	. . .	11	4	3	4	22
Enameled iron......	. . .	. . .	10	1	1	1	13
Galvanized	. . .	1	. . .	7	7	2	17
Lead............	. . .	. . .	4	. .	. .	2	6
Lead lined.........	1	. . .	5	. .	. .	2	8
Cement lined.......	. . .	. . .	16	6	5	. . .	27
Totals...........	1	1	46	18	16	11	93

from cement-lined pipes to some other material have occurred in 27 places.

A comparison of the number of places now using the different materials with the number of places where this material has been abandoned shows that 63 per cent. of those formerly using plain iron or steel pipes have changed to some other material. Eight per cent. have changed from galvanized iron; 19 per cent. from lead or lead lined; and 42 per cent. from cement lined.

Of those places where changes have been made from galvanized pipe to some other material, 13 are supplied from surface sources, 1 with ground water, and 3 with filtered water. Of the places changing from lead or lead-lined pipe to some other material, 5 are supplied from surface sources, 13 from ground-water sources, and 4 from filtered sources. Of the places abandoning cement-lined pipes for other material, 18 are supplied with surface water, 7 with ground water, and 1 with filtered water.

The reasons reported for the changes are varied. The changes from plain and galvanized pipes are almost entirely on account of rust. The changes from lead pipes are largely on account of the possibility of lead poisoning, although in some cases it has been on account of expense or because of the bursting of the pipes under pressure. Lead-lined pipe has been abandoned on account of lead poisoning and trouble from bursting and because of the difficulty in making joints which will not corrode. Of 20 places reporting the abandonment of cement-lined pipes, 8 were on account of

trouble at the joints, 6 "for convenience," and 2 on account of expense.

A large proportion of the places where the works have been in operation for a sufficient time report trouble with service pipes no matter what the material used, except in the case of cement-lined pipes. With cement-lined pipes, 54 per cent. of the places reporting report little or no trouble. With galvanized pipe, 36 per cent. of the places report little or no trouble, and with lead pipe 10 per cent. so report.

The trouble with iron and steel pipes, both plain and galvanized, appears to be through the entire length of the pipe. The trouble with lead pipes appears largely at the corporation cock. The trouble with cement-lined pipes is very largely corrosion of the outside of the pipe just inside the cellar walls, with some trouble at the lead gooseneck.

Life of Service Pipes.

The data in regard to length of life of a service pipe and the period that elapses before it begins to give trouble are very unsatisfactory. The averages of the figures given in the returns are as follows:

	Years before Trouble Begins.	Life of Pipe (Years).
Plain iron or steel	12	16
Galvanized	15	20
Lead	10	35
Lead lined	10	23
Cement lined	14	28

Where Trouble Occurs.

The main sources of trouble from corrosion are largely inside the pipes, due to the action of the water. In certain soils, however, there is a rapid corrosion of the pipes on the outside, and, if the inside is protected, as in the case of cement-lined pipes, this is the main source of trouble. Pipes laid in salt marsh or in cinder-fill are certain to be acted upon rapidly. Pipes in clay are much more subject to corrosion on the outside than those in sand or gravel. One of the common places where trouble occurs is at

the corporation cock, or, where a gooseneck is used, at the junction of the gooseneck with the service pipe. Some of the troubles at the corporation cock are due to the tuberculation of the inside of the main pipe, which tends to cover the end of the corporation cock. This can be overcome in a large measure by inserting the corporation cock well beyond the inside of the main.

The following table gives the location of the principal troubles with different kinds of services as reported to the committee.

WHERE TROUBLE OCCURS.

	Plain Iron or Steel.	Galvanized.	Lead.	Lead Lined.	Cement Lined.
Throughout entire length...	10	49	17	8	2
Couplings and fittings......	4	24	7	6	10
Cellar wall................	3	8	5	6	13
Corporation or gooseneck...	7	20	14	6	14
Curb cock................	3	8	6	2	4

THEORY OF CORROSION OF METALS BY WATER.

There are two main theories in regard to the corrosion of metals, — the carbonic acid theory and the electrolytic theory. According to the carbonic acid theory, which originated many years ago, iron is first dissolved by an acid, even weak acids such as carbonic acid being active. The ferrous salt formed by this corrosion is oxidized by the oxygen present in solution; the ferric hydroxide thus formed is precipitated, and CO_2 is liberated to act again on the iron. This is a cycle whereby a small amount of acid can effect the solution of a considerable amount of metal.

The electrolytic theory originated with Whitney, in 1903, and is based on fundamental principles of theoretical chemistry, the theory being that water and all substances in dilute solution are more or less completely dissociated into ions which convey positive and negative charges of electricity. Corrosion is caused, according to this theory, by one or more of the ions in solution being replaced by a metal. The hydrogen ions are most easily replaced, and hence are the active factor in corrosion. Anything in solution or any external force which tends to increase the concentra-

tion of hydrogen ions will increase the corrosive power of a water, while anything which tends to diminish the concentration of the hydrogen ions will decrease corrosion; for instance, metallic iron is attacked by the hydrogen ions, Fe going into solution as ferrous iron, and hydrogen changing from the ionic to the molecular or gaseous form.

According to this theory, iron should be attacked by the hydrogen ions in the purest water, and it probably is. Certain experiments, however, made at the Lawrence Experiment Station, in which iron pipes were tested with waters of varying character, seemed to show that pure distilled water, free from organic or mineral matters, had but slight corrosive properties unless free oxygen was present. Similar experiments with lead pipes gave like results. These results are in accord with those obtained elsewhere in studies of the factors influencing the corrosion of structural iron and steel, in which it has been proved many times that the presence of oxygen is an important factor.

The corrosion of metals by stray electric currents is well known, and these stray electric currents are of great importance as affecting the strength and life of water mains and other metal structures by corrosion. Small currents of electricity between metals of different potential are also important factors in the corrosion problem, and theoretical and electrical chemists have found by experiment that the metallic elements vary widely in electrical potential.

It has been shown that electric currents caused by unequal heating of different parts of a steam boiler are responsible at times for the destruction of boiler tubes. Impurities in a metal also cause local electrolytic action. The purest iron is thrown into nodes of positive and negative potential when immersed in water, and a scratch on the surface of polished metal may make it of different potential from the remainder of the surface and become the starting point of corrosive action. Iron, lead, or tin pipes, portions of which are wet and other portions dry, are apparently thrown into zones of varying potential, and corrosion occurs more or less actively at the junction of the wet and dry areas.

The factors entering into corrosion are too many to be enumerated here, but a review of them and a collection of references to

articles in regard to corrosion are given in an article published in the forty-second annual report of the Massachusetts State Board of Health, entitled, "Studies of the Relative Corrosion of Metal Pipes by Waters."

This committee is chiefly concerned with the practical corrosion of service pipes in actual use and the character of waters which will most actively corrode metallic pipes.

It was apparently shown by the State Board of Health of Massachusetts, in an investigation during 1898–1900 inclusive, that the cause of the taking of lead from the service pipes of certain towns and cities of the state (that is, the corrosion of these pipes) was the presence of a considerable volume of free carbonic acid in the ground waters supplied to these cities and towns. Corrosion of lead pipes was not serious in towns with surface-water supplies. It was shown during these investigations that soft water free, or comparatively so, from mineral matter, when containing some dissolved oxygen, attacked lead, and that the presence of certain other bodies as free ammonia, nitrates, etc., apparently caused the water to have some solvent action, yet that in actual practice with the conditions prevailing in the service pipes of a distribution system, a potable water in Massachusetts with a dangerous lead-dissolving action always contained considerable free carbonic acid.

It was also shown that the greater the hardness of a water compared with the free carbonic acid present, the less was the corrosive power of such water. This work was completed before Whitney published his article upon the electrolytic theory of corrosion, but the results in the light of further study seem to uphold the carbonic acid theory, although probably not at variance with the electrolytic theory.

Most New England waters have generally very little action on tin and copper, hence pipes of these metals are but slightly corroded by water unless electrolytic action occurs, owing to the use of connecting metals with different potential. Certain New England waters have a very decided action on iron and steel, and the softer the water the more likely is this action to occur. The corrosion of iron and steel pipes has been long noted, and extensive studies of the subject have been made in recent years, owing

to the occurrence in certain localities of what is known as the "red water plague." This has been studied from the consumer's point of view, and largely in regard to the corrosion of piping within dwellings. Articles in engineering papers since about 1909 have called attention to the occurrence of rusty or red water in many places, and have stated that such troubles were common and serious in the case of some ground waters and certain soft waters of the east and south which had been purified by mechanical filtration. Other writers have called attention to the fact that swampy waters also cause this trouble. An extensive investigation was made in regard to the Springfield, Mass., water in 1910. In this investigation the greater part of the trouble was found to be in places where the plumbing had been recently installed and where a poor quality of galvanized steel was used for pipes and hot-water boilers, and the trouble was stated to be due to electrolytic action either in the imperfectly galvanized materials or at the junction of unlike metals. This experience was with steel pipes, but it has been stated that in the municipal bath houses of New York City hot-water pipes have to be replaced frequently, and that there is apparently little difference in the rate of corrosion of galvanized iron and galvanized steel pipes. This has been noted at other places. In modern methods of manufacture, the line of demarcation between iron and steel is not clear, and it is probable that in some instances steel pipe is used when iron is intended for use, and vice versa. The fact that waters purified by the use of sulphate of alumina might be more corrosive in their action upon metals after than before purification, was first mentioned in the reports upon the purification of the Ohio River water at Louisville in 1899, and the suggestion was made that the corrosive action might be checked by the use of lime. The increased corrosive action in such cases is due to increased carbonic acid and the fact that a purer water results; that is, one containing less organic matter. A sand-filtered soft water is also more corrosive than the same water before filtration.

Corrosion and the Public Health.

The literature of corrosion in connection with public health is fairly extensive, and extends farther back than the beginning of

the Christian era. Hippocrates recognized the danger of lead poisoning in connection with water supplies, and the fact that water conveyed through lead pipes or held in lead cisterns sometimes became poisonous was commented upon by medical writers of the middle ages.

Twenty years ago there were many cases of lead poisoning in certain cities and towns of Massachusetts having ground water supplies and lead service pipes. From investigations in regard to these cases, and determinations of the amount of lead in the water used, it was decided that it would be safe to assume that the habitual use of water containing lead in an amount equal to, or greater than, 0.04 parts in 100 000 might cause lead poisoning. It is only fair for this committee to state, however, that lead pipe is in common use in many municipalities both as service-piping and in household plumbing, and apparently without ill effects to the consumers of the water passing through these pipes. The action of these Massachusetts waters upon lead was ascribed, as previously stated in this report, to the fact that they were fairly soft and contained considerable carbonic acid.

There is little to be found in regard to the action of zinc, tin, and copper in water supplies as affecting public health, and it is probable that few waters take enough of these metals in solution to have a toxic effect upon their consumers. There are only one or two instances that can be quoted in regard to disturbances of health caused by zinc, and these are not well authenticated. It is improbable that any amount of iron in water has ever affected the health of consumers except perhaps beneficially.

Plain Wrought Iron and Steel.

The committee believes that there are very few cases where the use of either wrought iron or steel pipes without some protective coating for services is justifiable. Such pipes are certain to become filled with rust, and the expense of cleaning or renewing them will much more than offset the extra first cost of coated pipes. Covering the metal with some protective paint seems to increase its life but slightly.

In the compilation of the returns, wrought iron and steel have been grouped together, as it is evident that the words are used

interchangeably in many cases. Of those making returns, however, very few have said that steel pipes were now used, and a considerable number have called attention to the fact that only genuine wrought iron was used. Others have stated strongly their belief in the superiority of wrought iron over steel, deeming it of sufficient importance to call for special remark.

The relative merit of steel and wrought iron has been a matter of controversy ever since steel pipe has been on the market. The steel pipe has the advantage of greater strength and lower cost, but the advocates of wrought iron claim that the steel corrodes more rapidly, has a much shorter life, and is more difficult to work. The advocates of steel contend that the life of steel is as long as, if not longer than, that of wrought iron. Both sides produce evidence to support their claims, much of which appears to be trustworthy. The claims of both sides, also, are supported by competent experts.

The behavior of pipes under different conditions is so different that the greatest care must be exercised in drawing conclusions. The action of different waters on both steel and wrought iron is quite different, so that the results obtained in different places cannot be compared. The action of the water on a pipe depends to a considerable extent on the quantity passing through it, and a pipe which contains dead water much of the time will corrode much less rapidly than one which has a continuous flow. For these reasons, conclusions based on the appearance of occasional samples are worthless, and even two pipes side by side may not be comparable, owing to a difference in the flow through the pipe. The character of the metal should also be taken into consideration, as there is wrought-iron pipe, for example, which is of inferior quality and will not resist corrosion as well as high-grade wrought iron, and there is undoubtedly much steel pipe sold as wrought iron.

In regard to the working of the steel, there seems to be no doubt that the same tools used for wrought-iron pipes cannot be satisfactorily used for steel pipes, but that with suitable tools the steel pipes can be worked without any difficulty.

The experience of water-works superintendents as indicated by the returns and as shown by previous discussions in the meetings

of the Association is decidedly unfavorable to steel pipe, and while, undoubtedly, many of those who argue in favor of wrought-iron pipes may be unfamiliar with anything else, and believe in it because they were taught to believe in it, there is certainly a large number of reliable men who have had an extended experience with both materials who are firmly convinced that wrought iron is much superior to steel, and it would seem that there must be some good reason for this belief.

The feeling against steel pipes appears to be chiefly confined to New England, for it is undoubtedly a fact that a majority of the service pipes used in other sections of the country are of steel, and it is apparent that no more trouble is experienced from the use of steel in these places than is experienced from the use of wrought iron in this vicinity.

Galvanized Pipe.

The action of water on zinc is comparatively slight, and if the pipe — whether of steel or wrought iron — is completely covered with zinc the life of the service will be very materially lengthened. The chief trouble with galvanized pipe is in the joints, where the water gets directly at the iron, and in the imperfect covering of the iron or steel.

As pipes are manufactured, there is a large quantity of scale left on the pipe, especially on the inside. In the galvanizing process this scale is simply covered with zinc. When the scale becomes loose, as it invariably will, the metal of the pipes is, in spots, exposed directly to the action of the water and corrosion begins, which tends to loosen still further the scale, and soon the pipe is little better than an uncoated pipe. The wrought-iron pipe advocates claim that the greater roughness of the wrought iron insures a greater quantity of zinc, but the extra zinc in this case is obviously not so distributed as to be of any material value.

If the pipe could be freed from scale before galvanizing, leaving a comparatively smooth surface, the effects of galvanizing would be much greater, as there would be little opportunity for the direct action of the water on the iron. The National Tube Company has now perfected a method of removing scale from the

pipes much more effectively than has heretofore been practicable, which would seem to be of enormous advantage both in decreasing the friction in the pipe and especially in making it possible to obtain a much more durable coating of zinc when galvanized. This process, which is applicable both to wrought-iron and steel pipes, is likely to result in the production of very much better galvanized pipe.

Galvanized pipe appears to be the cheapest practicable material for services where the class of street surfacing is not such as to make the renewal of the services a matter of great expense. Services of this material will give trouble, especially with waters which attack metals readily, but there is no possibility of danger to health in their use.

Whether steel pipe is as durable when galvanized as is wrought iron, is a matter which is open to discussion. If the galvanizing is perfect, it would make little difference whether the metal under the zinc resisted corrosion more or less. With the process for removing scale above referred to, it would seem that a long step had been made towards getting a perfect galvanized pipe.

Lead Pipe.

Lead is in many respects the most satisfactory material to use for service pipes. Its pliability and its comparative freedom from corrosive action make it almost ideal from a mechanical standpoint. The cost of lead pipe of sufficient thickness to safely withstand the pressure is more than the cost of many other materials used for services, but in a paved street the greater duration of life probably more than compensates for the extra cost, and in places where the streets are occupied by other pipes and conduits the ease of getting over and under these obstructions with a flexible pipe is a great advantage.

The most serious objection to the use of lead pipe for services is the possibility that the water may dissolve enough lead from the pipe to cause lead poisoning. It is certain that many cases of lead poisoning have been caused by the use of lead services, and water companies have had to pay considerable amounts in damages where they have supplied water through lead pipes and lead poisoning has resulted. On the other hand, lead has always been

used for services in most of the large places without any known unfavorable effects.

The reason why trouble has resulted in some places and not in others is found in the different character of water supplied in these places. With soft water which contains considerable carbonic acid, the action of water on the lead is very rapid. Waters obtained from reservoirs are not likely to have carbonic acid, and instead of a corrosive action the water tends to form a coating of an insoluble lead compound on the inside of the pipe. With such waters there is no great danger in the use of lead except, possibly, when the pipe is new. The danger in such cases lies in the possibility that at some future time the character of the water will change either by the introduction of new sources of supply or by filtration of the old supply.

It seems to be practically impossible to determine definitely in advance what the effect of any water on lead pipe will be, as the laboratory results fail in many cases to show the action which will occur in actual practice. Tests of service pipes in use for a considerable period are the only safe guides.

The health authorities of several of the New England states advise most strongly against the use of lead for service pipes, even where the character of the water now in use is such as to indicate that there would probably be no injurious effects.

Lead-Lined Pipe.

Lead-lined pipe as manufactured several years ago gave much trouble from the separation of the lead lining from the iron, leaving the metal exposed to the water. The pipe as manufactured to-day, however, appears to be durable and prevents the corrosion of the iron or steel very effectively. It would seem that the life of such pipe would be limited only by the corrosion of the outside of the pipe.

The expense of the lead-lined pipe is much less than that of lead pipe, and it has the advantage of greatly increased strength. On the other hand, it does not have the advantage of flexibility.

All of the dangers from the dissolving of lead which have been enumerated in the case of lead pipes apply equally to lead-lined pipes.

Cement-Lined Pipes.

Cement-lined pipes, if properly constructed, make ideal service pipes as far as the interior of the pipe is concerned. The cement is not acted upon by water and the interior of the pipe will remain smooth for an indefinite time. There are many places where cement-lined pipes have been in use for many years without any trouble, and there are many other where they have given so much trouble that their use has been discontinued. As far as the committee has been able to learn, the troubles with cement-lined pipes have been almost entirely from imperfect work or from the use of fittings which did not prevent the water from getting to the metal.

For lining pipes, Rosendale cement is most commonly used, although in some places Portland cement has given good results, and a mixture of the two cements has also been used.

The methods of making joints which will not cause trouble are described in the discussion. The simplest method appears to be to line the coupling with the pipe and then dig out the cement from the coupling to receive the other pipe. The placing of a nipple temporarily on the end of the pipe while it is being lined appears also to have been successful. In some places lead-lined couplings have been used or brass ferrules have been inserted. In general, it may be said that the best method is that which most nearly preserves a smooth and unbroken lining of cement.

Cement-lined pipe can be bent sufficiently to pass ordinary obstructions in the street, but it should not be used until the lining has been on for a sufficient time to allow the cement to become well set,— a period of several weeks.

Several of the smaller plants have abandoned the use of cement-lined pipes on account of the trouble and expense of lining them. Within the past few years, cement-lined pipes and fittings have been put on the market, and it is claimed that they can be shipped without serious injury. If this claim is well founded, and the evidence indicates that it is, the use of this material will be much more practicable in the smaller places.

Trouble with cement-lined services occurs most frequently from corrosion on the outside of the pipe, and especially where the pipe enters the cellar. In many cases the action on the outside

of the pipe is quite rapid, and samples have been submitted to the committee where the iron has been completely eaten through and nothing but the cement remains to hold the water. This rapid corrosion is probably due to the dampness inside the cellar wall. Various methods have been suggested for remedying this. A short piece of the pipe where it passes through the cellar wall may be encased in cement, or a short section of brass pipe may be used from the outside of the cellar wall to the stop and waste. Another suggestion is that a coupling be placed just outside the wall, so that the corroded piece may be readily removed and replaced. Painting the outside of the pipe is resorted to in some places with good results.

The use of galvanized pipes for lining with cement undoubtedly gives the pipe a much longer life, as the outside is in this way protected from corrosion to a large extent.

Pipes of Other Materials.

Other materials have been used to some extent in the construction of service pipes. The enamel pipe which was common some years ago has practically gone out of use, although there is one town in Massachusetts which has recently adopted it and has installed a considerable number of services of this material within the past two or three years. The claim is made in this case that the enamel is of considerably better quality than that formerly used, as it has been given severe tests and passed through them satisfactorily. The test of time, however, has yet not been applied.

Tin has been used to some extent, and is an ideal material for service pipe work, but the great expense of the tin makes it practically out of the question.

Brass is used in a few cases, especially where the corrosive action is likely to be great, but the expense of brass pipe is too great to make it practical at the present time.

Size of Service.

The standard size for services is ordinarily $\frac{3}{4}$ in., but in several cases this size has been increased to 1 in. or even to $1\frac{1}{4}$ in. for the purpose, chiefly, of lengthening the life of the service. Where

plain or galvanized steel or wrought-iron pipes are used, the pipes soon begin to fill up with rust, but the service which they render is fairly satisfactory until the pipes become nearly choked, when they must be cleaned. A 1-in. pipe has about twice the area of $\frac{3}{4}$-in. pipe and will probably last at least twice as long before it will require cleaning. Where meters are not used, there is some objection to the use of large service pipes, as the waste of water from leaks and from carelessness and the use of water through garden hose is considerably greater with the larger service. Where meters are used, this objection does not apply, and it seems to the committee that much trouble and expense might be saved, where pipes are used which are liable to corrode, if the services should be made of larger size. Furthermore, a $\frac{3}{4}$-in. service pipe of any considerable length will not, in many cases, give a satisfactory flow of water to meet the modern requirements.

The extent to which larger service pipes are used is shown in the following table, which gives the standard size reported by those making returns.

Standard Size of Service. (Inches.)	Number of Places.
$\frac{1}{2}$	16
$\frac{5}{8}$	33
$\frac{3}{4}$	198
1	51
$1\frac{1}{4}$	5
$1\frac{1}{2}$	2

Goosenecks versus Rigid Connections.

Rigid connections with the main and the omission of the goosenecks are used in a large number of places, and in some places such connections are used exclusively. The advantages of the rigid connections are obvious. They make a considerable saving in the first cost, and they are much more readily cleaned. On the other hand, the gooseneck permits the dropping of the service below the main and away from frost, and it is possible to make the service take any direction from the main.

The cost of using goosenecks and the troubles which result from them have been considerably reduced by the use of lead

flange connections instead of wiped joints. Judging from the testimony of those who use them, the lead flange connections have given much better satisfaction than the wiped joints and can be made by any workman.

Where rigid connections are used, it is necessary to have the pipes rest on a firm foundation, as any settlement in the service pipe near the main may cause the service to break. The digging up of the street near the main may also cause trouble to rigid connections. The fact that 83 towns report the use of rigid connections to a greater or less extent, and that 56 of these report no trouble, and many others " little trouble " or " some trouble," would indicate that the use of rigid connections is thoroughly practicable in many places. In the larger cities, where the streets are occupied by many pipes, conduits, and other obstructions, and are frequently dug up, it would not seem wise to attempt to use the rigid connections.

Cleaning Service Pipes.

During the past few years great advances have been made in the methods of cleaning service pipes, and it is now possible to save large sums which have heretofore been paid for digging up the services and for renewals. The committee has not discussed the merits of the different types of cleaners, but all of them seem to have some merit. The most satisfactory in many cases, and especially with lead pipes or when goosenecks are used, is the force pump and wad of paper, which permits the cleaning of the gooseneck and corporation cock as well as the straight pipe.*

Method of Paying for Services.

Custom varies as to the method of charging for services, but in New England the general custom is for the department to pay for the service from the main to the curb cock or to the property line, the remainder being paid for by the owner. Outside of New England the custom appears to be quite different, and in the majority of places making returns the customer is obliged to pay practically all of the cost of the service from the main to the house.

* Journal N. E. W. W. A., Vol. XXVIII, p. 70.

The following table gives the proportion of the cost of the services paid for by the water departments in New England and in the states outside of New England.

PORTION OF SERVICE PAID FOR BY WATER DEPARTMENT.

	Number of Places.		
	New England.	Other States.	Total.
None	41	38	79
To curb or property line	174	10	184
Corporation	8	4	12
Corporation and curb cock	3	...	3
Miscellaneous	15	2	17

PORTION OF SERVICE LAID BY WATER DEPARTMENT.

The almost universal opinion among superintendents, especially in New England, is that the water department should lay and maintain all the services from the main to the stop and waste in the cellar, whatever portion of the expense may be borne by the department. The superintendents in many places where this is not now done express themselves very strongly in favor of it, as the department can then prevent much of the leakage from defective services and prevent much of the trouble from freezing.

The following table gives statistics in regard to the portion of the service which is laid by the department and the portion laid by the owners.

PORTION OF SERVICE LAID BY WATER DEPARTMENT.

	Number of Places.		
	New England.	Other States.	Total.
None	27	17	44
To curb or property line	94	24	118
To cellar	117	6	123
Corporation	...	6	6
Miscellaneous	2	...	2

Conclusions.

Service connections may and frequently do give more trouble than any other part of a water-works system, causing the deterioration of an otherwise good water and constituting an unduly large proportion of the maintenance expense. The preservation of the purity of the water is obviously the most important requisite, and only those materials should be used which will not impair in any way the quality of the water.

The cost of the installation of services is so small in comparison with the total cost of the system, and the expenses for repairs and renewals are so large, that only the most durable materials should be used.

There are very few, if any, places where it is advisable to use uncoated wrought iron or steel in service-pipe construction. The metal will corrode more or less rapidly, according to the character of the water, clogging the pipes, giving trouble in the houses from rusty water, and eventually requiring renewal of the service.

The use of galvanized pipe decreases very materially, in most cases, the troubles experienced from the use of plain wrought iron or steel. With some waters, galvanized pipes will give little or no trouble and will last many years. With other waters, the zinc will be rapidly dissolved and the pipe will then become no better than an uncoated pipe. Better methods of galvanizing will undoubtedly produce better results in service, and the process now being adopted of removing scale from the inside of the pipe before galvanizing gives promise of good results.

Lead pipe is mechanically an almost ideal pipe for services, on account of its flexibility and the ease of laying in streets where there are obstructions. With waters which do not attack the lead, this material is almost indestructible unless subjected to the action of electrolysis. The lead does not corrode and the pipe remains smooth and clean. The serious objection to the use of this material is the possibility that it may affect the health of those using the water. It is certain that lead services have been in use in many places for a great number of years without any known serious results, and it is equally certain that in other places where they have been used, very serious results have ensued, involving loss of life and the payment of heavy damages therefor.

Many waters act on lead to produce insoluble carbonates on the inner surface of the pipes.

The action of the water on the lead depends on the character of the water and the addition of a new source of supply, or the filtration of the water may produce conditions entirely different from those which now obtain. One case of this kind is referred to in the discussion.

It seems to be practically impossible to determine in advance by laboratory tests whether or not the use of lead will be safe. The only sure test is one of several years' duration in actual service.

In view of the serious consequences which may result from the use of lead, the committee believes that in new works, at least, it is advisable to use some other material for services. In those places where lead has always been used and it is known that the water does not dissolve the lead, its use may be continued until something occurs to change the character of the water, when the effect of this change should be carefully watched.

Lead-lined iron or steel pipe, like lead pipe, will retain a smooth and clean interior, and, as far as the action of the water is concerned, will last for a long period. It has the merit of being stronger and cheaper than lead pipe. The outside of the pipe is subjected to the action of the soil and of the atmosphere, and, unless protected in some way, will rust out as in the case of other material.

Lead-lined pipe carries with it all the possibilities of danger to health that attend the use of lead pipe.

Cement-lined pipes are the most satisfactory, so far as the action of the water is concerned, of any which are now used for services. The difficulties which arise from the use of this material are solely mechanical. Water has no appreciable action on cement, and the cement lining, if properly constructed, will last for an indefinite time.

The troubles which have occurred appear to be due entirely to imperfect work either in lining the pipes or in making the joints. Unless the outside of the pipe is protected, corrosion will take place, the same as in the case of plain and lead-lined pipe.

The waters which will attack metals most actively are, in general, the soft, clear waters. Ground waters are more apt to attack metals than surface waters, and hot water has more effect than cold. Filtered waters are much more active than unfiltered waters.

Waters which attack one metal will, in general, attack another, and changing from iron pipe which corrodes badly to lead pipe is likely to produce a dangerous condition. The reason why galvanized pipe is more satisfactory than plain pipe is that the action of the water on the zinc is somewhat slower, and the products of the corrosion of zinc are soluble and innocuous, but the zinc will be eaten through in time and the iron will then be open to attack. The more water which passes through the service, the more rapid will be the action on the metal. Stagnant water will have little effect.

Corrosion of the outside of the pipes is a serious matter, especially in the case of lined pipes, where it generally determines the useful life of the pipe. Outside corrosion is especially serious in clayey soils, in salt-water marshes, ashes or cinders, and near stables. The greatest troubles from this cause, however, occur just inside the cellar wall.

For corrosion in the soil, the best remedy is to use a coated pipe, and in many places where cement-lined pipes are used, the pipes are galvanized. Where the pipe passes through the cellar wall, a pipe encased in cement may be installed, or a short length of brass pipe may be used. In some places a coupling is placed just outside the wall, so that a short section can be readily removed and replaced.

With regard to the relative merits of wrought iron and steel, the great majority of users of these pipes testify strongly in favor of the former. It is undoubtedly a fact that the strong preference for wrought iron is confined chiefly to New England, and that steel is used very generally in other sections of the country.

The experience of superintendents indicates that the steel corrodes more rapidly than wrought iron, and some claim that it is much more difficult to work, although it appears from the testimony of many others that there is no difficulty in cutting and threading the steel pipes if proper tools are used, the tools ordinarily used on wrought iron not being suited to use on steel.

The concensus of opinion among water-works men in New England is that the water department should lay and maintain all services from the main to the stop and waste in the cellar.

Custom varies as to the method of paying for services, but in

New England the general custom is for the department to pay for the services from the main to the curb-cock or the property line. Outside of New England, in the majority of cases the customer pays practically all of the cost of the service.

Rigid connections with the mains appear to possess many advantages over the use of a gooseneck, and the experience in many places shows that there is no trouble to be expected where the soil is suitable and there is not much digging up of the streets for sewers and conduits.

Lead flange connections appear to be superior to wiped joints.

The committee believes that in many cases the standard size for services can be made one inch to the advantage both of the consumer and the department. The requirements in the modern house are much greater than in the past, and some plumbing fixtures require a larger flow than can be obtained through a $\frac{3}{4}$-in. pipe of the average length and with ordinary pressure. The use of meters will control the waste which otherwise might be greater with the larger service. In a pipe which tends to fill up with rust, the larger service will last much longer before cleaning is necessary than the smaller pipe.

Respectfully submitted,

William S. Johnson,
H. W. Clark,
George A. Stacy,
William F. Sullivan,
Alfred E. Martin,
Committee.

Discussion.*

Mr. R. C. P. Coggeshall.† In June, 1884, Walter H. Richards, of New London, Conn., presented to this Association a remarkably able paper entitled, "Service Pipes, Material, Size, etc." This was followed by a lively discussion. That was thirty years ago, and yet that paper reads as well to-day as when written. Indeed, the whole discussion would pass well for a product of a meeting

* On the preliminary draft of the committee's report, submitted September 14, 1916.
† Superintendent Water Works, New Bedford, Mass.

held to-day. It is interesting to look over the replies to the questions submitted to the members at that time. The questions were as follows:

1. *Lead Pipe.* Please state sizes used by you, giving weight per foot and head in pounds pressure for each size used, and also whether you have had any bad results from the use of this pipe.
2. *Wrought-Iron Pipe.* Please state the kind used and your experience with same.
3. Please state the kind you are now using and your reason therefor.
4. Please state the kind of service pipe you would prefer to use, and your reasons therefor.
5. Please give information acquired by your experience in the use of service pipe which would be of interest to the Association.

The tabulations which may be found in the Proceedings of 1884 show forty-one replies to these questions. Of this number, the pipe in actual use in the various departments represented was,

Lead.	Galvanized Iron.	Enameled.	Cement Lined.	Tarred Wrought Iron.
10	9	6	9	7

The preferences of the superintendents submitting replies were,

Lead.	Galvanized Iron.	Enameled.	Cement-Lined Wrought Iron.	Tarred Wrought Iron.	Brass.
20	5	3	5	7	1

The enameled wrought-iron pipes of those days have long since disappeared, proving to be worthless, and a most excellent pipe known as lead-lined wrought-iron has since been developed, and appears to be giving satisfaction to those using it.

At the time stated, the speaker gave his preference for lead pipe. During the additional thirty years which have followed he has seen no reason to revise that opinion. In reply to those who seem to fear trouble due to lead poisoning, would say that every locality should determine for itself whether or not the quality of water is proper to permit the use of lead pipe. We all know that it cannot be safely used in all waters. In all of my long years of experience I never knew a case of illness which could be attributed to the use of lead pipe, in supplying our customers through the fifteen thousand services now in commission.

Mr. E. C. Brooks.* I think that most of you will agree that lead is an ideal metal for a supply pipe. It certainly has a great many things to recommend it, — in that it can be easily connected, and from the nature of the metal adjusts itself to the expansion and contraction due to the heating and cooling of the water in the ground. In these days, when streets are so well made and paved, and granolithic sidewalks laid, of course it becomes necessary to so put in service pipes that they shall require attention or repair as seldom as possible. Its being able to fulfill this requirement adds, of course, very materially to the worth of the lead pipe for services. Although lead pipe may not tend to corrode or fill up, as some of the other services do, still we know that composition fittings do fill up and that it is necessary if possible to clean them out.

I believe that a service pipe connected on the horizontal diameter of the pipe, without any crooks or bends or anything of that kind, answers the purpose better than those put in with any of the so-called goosenecks. Certainly if it is possible to clean anything it can be cleaned as a straight pipe, whereas if you use a gooseneck you have got to take the pipe up anyway. I have had some experience in cleaning services, and must say that some of the work was very gratifying indeed.

We know that there are sections where lead pipe is looked upon with horror as a water carrier, and a great many persons have very strong feelings in regard to having anything in the way of drinking water pass through lead. Of course where that feeling prevails we are obliged to resort to either galvanized iron or some of the lined supply pipes for service lines. And they of course cannot be laid much cheaper, if any cheaper, than lead — that is, for ordinary pressures. But I think that all who have had much experience with iron services must have had trouble due to the expansion and contraction of the service and the breaking off of the curb cocks from that effect. It has occurred to me that possibly a cheap expansion joint might be put in adjacent to the curb cock that would overcome the difficulty and avoid that trouble.

The galvanized-iron or lined supply pipe can certainly be

* Melrose, Mass.

cleaned very readily and very thoroughly. I have thought that probably in the future we are going to have a flexible cleaner, after the manner of the flexible connections used in machine shops in drilling, and by the dentists for driving their drills and burrs. There is electricity in almost every house that you come to now, and a small motor connected to a flexible shaft can certainly very readily clean out a supply, and do it thoroughly.

There is one thing that bothers us in these days, and that is the freedom with which the public-service corporations are allowed to put their conduits in the streets. In street after street the water pipes are blanketed by the public-service corporations' conduits, so that in putting in a supply you have got to offset under them or over them, and resort to all sorts of means to get round them. It seems as though the municipality ought to have the right of way in the street, and that a zone should be reserved for their pipes, free from obstruction by conduits or other pipes.

Mr. W. H. Richards.* The first requisite of a service pipe is that it shall be sanitary; that is, that it shall not affect the water passing through it in a manner deleterious to health. All other qualifications are subordinate to its permanence, or lasting qualities, and this is particularly the case in these days of improved roads and permanent pavements.

A moment's thought will show any practical man that true economy demands that any structure built underground should be of the most permanent and lasting character.

A large portion of the cost of a service pipe is composed of the labor cost, which, when the pipe is relaid, has to be duplicated, so that, even if it has to be repeated only once in twenty-five years, it is done at a distinct loss.

I think that it may be said, without danger of refutation, that, after a trial of a thousand years or more, lead has proven the most permanent service pipe, and next to that brass, which has been universally used for the fittings.

In the few cases where it is distinctly proven that the water is of such quality that it will attack lead, brass might be substituted; but it is somewhat doubtful if water which would attack lead would not also corrode brass.

* Engineer, New London, Conn.

But, as more or less brass and lead is used on all fixtures throughout any work, the question is one of degree, and this raises another question, — Is such a water fit to be taken into the human stomach?

Latterly it has become the fashion to select a water supply, the water of which requires dosing with bleaching powder, and the stomach that can stand that ought not to revolt at a little lead.

In fact, I think it could be shown that, where a water supply is of such quality as to attack lead service pipe to a harmful extent, it should be abandoned for a new supply.

Regarding the purely economic aspects of this discussion, I may say that the first cost of service pipe, per foot, in the city of New London, has not materially changed in forty years, although in that time we have changed from cement-lined to lead.

In conclusion, I would say further, that, with a few typographical corrections, the paper by the writer, which was published in the proceedings of 1884, still expresses his opinions.

Mr. F. F. Forbes.* For forty years we have used in Brookline a wrought-iron pipe lined with cement, and in that whole forty years I have never had a failure within the straight pipe; I have never taken out a pipe that has shown any signs of rusting through of the iron or an accumulation of anything on the cement; the bore has always been clear.

We have had some trouble where the iron pipe connects with the shut-off in the sidewalk. In the forty years of my experience there have been twenty-five or thirty cases where the pipe has broken down quite a bit at the curb cock; but never in the lining of the pipe, even where the pipe is joined together.

We always use a gooseneck at the main — a piece of bent pipe. One reason for that is that in Brookline the streets are dug up constantly. They dig under our service pipes, and we don't know about it until the thing is all done; but in this way we save a great many leaks. I have had those goosenecks almost straightened out, and a great many of them have been broken off. But I would rather a gooseneck would break than some other part of the pipe.

I find that you can bend a cement-lined pipe and it does not

* Superintendent Water Works, Brookline, Mass.

hurt it a bit; it does not crack. I have tried it time and time again. You can make an easy bend ten feet in diameter, and the cement does not crack a bit.

We used to use the F. O. Norton cement, but we cannot get that now. We use the best grade of American cement.

I might state briefly how we line the pipe with cement. After our pipe is delivered, we take off the couplings and reverse them and put them on the other end of the pipe. Although we buy plugged reamed pipe we run the reamer through all the pipe again, to be sure that there are no bunches left. We sift our cement through a very fine sieve because, in the best of cement, there are apt to be little lumps. After a pipe has been lined for about a week, we mix up a thin grout in a waterpot and run it through all the pipe, — lay it down on the floor and take it up and run through a rubber cone. We use the same cement for grout as is used in lining the pipe. By grouting the pipe in this way we cover up any little porous places and get a very smooth surface. We now dig the couplings out, which are all made on solid. We use a gage and dig them out so that the pipe will make up the last thread and then butt on the cement. Then we make up to the last thread — not too far to injure the lining.

We use Byers' galvanized wrought-iron pipe. We have some salt marsh and a good deal of filling in Brookline, and we find that plain wrought iron corrodes in a very short time.

In lining the pipe I run two cones through once, one cone behind the other, and then run them through a second time. The second time I revolve the pipe as the cone goes through, to keep the cone from going to the bottom side of the pipe.

We have six men that line pipe, and they can line between four and five thousand feet of pipe a day.

For 1-in. service pipe we use a 16-ft. length, but on a 2-in. we use a longer length. In using this length the cement will not run in back of the cone.

Mr. E. D. Eldredge.* One principal feature of the Onset water is its extreme softness. Sometimes the report of the State Board of Health analysis has shown zero on the scale. For that reason we have trouble from the color of the water, derived from

* Superintendent Water Company, Onset, Mass.

the cast-iron mains. That is the worst trouble we have. About every week we have to devote a whole day to blowing off in different sections of the town, and we have to do it systematically, so as to renew the whole contents of the pipe.

We used galvanized services for some years, but found that after a while the galvanizing came off and the pipe seemed to gradually close up and rust at the joints and the couplings, and tubercles formed; so we introduced cement-lined services, about 1897, and since then we have had no reason to regret it. Every case has been satisfactory. We have had no services stop up, although I have no doubt that at places the flow is decreasing.

With galvanized services the amount of formation depends very decidedly on the amount of water passing through. In some cases where a pipe is carrying water the year around, particularly a small constant flow, the pipe seems to collect rust, and in time it almost closes up. On the other hand, services that are in houses that are occupied but a short time — two or three months in the summer — seem to be in good condition yet. So it depends largely upon having a constant supply of new water. If the old water remains in the pipe, it doesn't seem to injure the pipe at all.

The cement lining process is done with some care, and always by the same men. We have three men that operate on it, and every piece of pipe is carefully inspected from both ends. In order to insure the success of the inspection as well as the convenience in handling the pipe, we cut every length in two, cut a new thread, reverse the coupling, make sure that both threads are good, screw the couplings on tight, perhaps a little tighter than in an ordinary joint, so that the couplings will not start again. Then in the process of ordinary cementing the coupling is lined, and the next day, after the cement is partly set, the coupling is reamed out so that the end of the cement presents a square surface for the end of the next pipe to butt up against, our idea being to obtain a continuous cement surface. The question would come up whether, if the pipe butts too hard, it would not scale the cement off. We have never had any trouble with that; it is more of a grinding process. The movement and the advance of the thread pulverizes the cement rather than scales it off, so,

as we lay a pipe, we turn the water on and wash that powder out and there is no further trouble.

We try to have a pipe seasoned six months before it is laid. That insures better quality and also makes less trouble with tastes of the cement in the water. That is a thing we have to caution everybody about, that for a little while there will be trouble with that. But it is only from water that has stood in the pipe several hours. It is of no use to let a flow occur with the idea of washing it out, because it won't come out for some time at any rate. But, if the water is drawn out that has stood in the pipe for several hours, then the new supply will not be tainted.

As far as the quality of the pipe goes, we have used straight wrought iron. We have had a little experience with steel. Once in a while we get hold of a piece, but, with the difficulty of cutting and the occasional splitting of the pipe and the immediate formation of rust on the outside, we have never used it. Although its price is much in its favor, we prefer the wrought iron. As our soil is sandy, it is quite favorable, so that the outside of the pipe is not seriously attacked.

We use rigid connections exclusively, and have never had any trouble. In tapping the main, we tap it on the side and put a level on the shank of the tap so as to show that the tapping is level if it is desirable to have it so.

For lining, I have a sausage machine made by the Bell Company, 6 in. in diameter and about 18 in. long, a good deal larger than the ordinary. It is very convenient to operate. It operates with a gear instead of a screw. It is quicker to operate, and the pistons are fairly tight. I put a leather packing on them and change the nozzle at the head of the cylinder and put on a bushing so as to take any size from three-quarters up to two inch. It is necessary, in mixing the cement, to be very careful about it and to mix it thoroughly, — stir it all up, and the more time spent in mixing the better it looks. I heard some remarks here about cement dropping, but we have never had any trouble of that kind.

Mr. J. C. Whitney.* Newton started in, on account of some experiments that were made, with the idea that, however bad other kinds of coated wrought-iron pipes might be, the galvanized

* Water Commissioner, Newton, Mass.

was the very worst, — that Newton water would probably take off the coating inside of three or four years, absolutely destroy it. The trouble was that the water they used in making their experiments was not the water actually used for the supply of the city.

They took plain river water, with the idea that it would come very near to being equivalent to the water which they intended to get, which was taken from the land adjacent to the river, and when the chemists reported that the galvanizing would disappear in the course of a very few years, it was taken for granted that they must use some other form of pipe. Lead pipe was expensive. Some people objected to it, of course. Brass pipe was out of the question. They tried experiments on various other kinds of coated pipes, and finally came to the conclusion that a tar-coated pipe, if some special pains were taken in the coating, would probably be the most satisfactory. They induced a firm in Boston to put in a vat, and subjected pipes to considerable immersion in a hot mixture, and they really did take special care, but I think the mistake that was made was in using $\frac{3}{4}$-in. pipe instead of 1-in. I really believe that if they had used 1-in. pipe instead of $\frac{3}{4}$-in., practically the whole of the services in use would be intact to-day. They used $\frac{3}{4}$-in., however, and when you get a quarter of an inch of rust, on an average, on a $\frac{3}{4}$-in. pipe, there isn't much space left.

After the works had been in operation eight or nine years, one of the inspectors took it upon himself to note the condition of the pipes in the houses where people had run a half-inch pipe, which a good many of them had done, from the cellar walls to the sinks, and found out the condition of the half-inch pipe in connection with the kind of pipe it was. He made a memorandum whether it was poor, fair, or good, and also the kind of pipe they had used. It was noted that the only people who were getting a satisfactory flow through that half-inch pipe were the ones who had used galvanized pipe.

The question was then raised by some one in connection with the works, whether galvanized pipe was not the best thing for us. A few experiments were made, and it was found that it was, so it was finally adopted, — about 1906, I believe. Since then prac-

tically nothing but galvanized pipe has been used except in cases where people demanded something else, as they do occasionally.

So far as I can discover, the galvanized pipe was the best thing for our water. Now we are using a 1-in. pipe, partly with the idea of furnishing ample water for any purpose and partly with the idea that, if the galvanizing does come off some day, we will have allowance for filling up. We never had to replace any galvanized pipe.

We endeavor to get strictly wrought-iron, galvanized. We occasionally have had a little steel pipe, but the galvanizing does not seem to stand very well, and it rusts much more rapidly than the wrought-iron.

We have all kinds of soil, and we are getting to have pretty well occupied streets, so it seems to us that there is some advantage in using the lead connection instead of rigid connection.

Mr. R. J. Thomas.* I want to go on record in favor of the rigid connection of service pipes to the main. In the early days of the water works at Lowell, in putting in the iron pipes they used the gooseneck, but for the last fifteen years, possibly, we have made our pipe connection on the corporation cock without a gooseneck, and find it gives us a great deal less trouble than the old gooseneck. Many of our leaks that we have from time to time we find occur on the gooseneck, and I can't recall a single instance where we had a leak on a service pipe where the connection was made direct and straight from the main pipe. If we meet an obstruction like a gas pipe, if it is in a large gas main, why, we have the gas company take it out of the way. If they don't do that — if it is too large — we bend the pipe; but we have not for many years made any connections with goosenecks.

I would also state that for the last fifteen or sixteen years, possibly longer, we have been using lead-lined pipes. We started in when they were first made because of the fact that the lead-lined pipe was cheaper than the lead pipe, — and we have got many services, hundreds of them, in use in our city, made of lead-lined iron pipe, that have given good satisfaction, and we have had no trouble with them, and with the rigid connection.

I have had experience with lead pipe, and I, like many other

* Lowell, Mass.

water-works men, believed in lead pipe on account of its economy and ease of handling. But there came a time when the water supply was changed to a ground supply that had a lot of carbonic acid gas in the water. This city had adopted, for a great many years, lead pipe. This city has over 12 000 services at the present time, and the first service, the No. 1 service on the book, is a cement-lined iron pipe, which was in use after forty years. In the interim they had adopted a lead pipe, and had put it in generally, and both the water department and the plumbers believed that that was the only proper pipe to use. But, as I said, there came a time when the water was improved; and in the improving of that water and introducing ground-water supply, tests showed after a while that this water attacked lead pipe. And then developed in some sections of the city — one particular section supplied by a particular ground water — a number of cases of lead poisoning, or supposed lead poisoning. The state authorities investigated it, and they almost issued an ultimatum to the department that any water that contained over .05 of one part in 100 000 parts was dangerous — and there was reputed to be one eighth. I don't know how true that is; it was reputed to be so. Although the water department combated that idea, the state authorities thought so. So, about that time, I believe, the State Board of Health doomed this lead pipe, and since then I do not believe that in a great many cities, in Massachusetts particularly, the lead pipe has been used without the sanction of the State Board of Health.

Mr. W. F. Sullivan.* The works in Nashua, N. H., were built in 1853, and for many years thereafter they put in the ordinary wrought-iron pipe. Then came the so-called enamel pipe and other kinds of pipes. For the last ten years we have used nothing but galvanized wrought-iron. I say wrought-iron pipe advisedly, because we trust that we get wrought-iron pipe all the time.

We use rigid connections entirely, and haven't had any trouble. The nature of the soil is rather loose and sandy. We can drive services under a street and sometimes wash them under a street. We use the 1-in. galvanized iron pipe, and think the life of the

* Superintendent Pennichuck Water Company, Nashua, N. H.

pipe will be as long as many of the older pipes that lasted anywhere from twenty-five to forty years. We think it pays to use the large diameter.

We use plug cocks in the cellar up to two-inch, and have some trouble inside in the cellar wall, the pipe rusting out and getting rather thin right there.

We furnish the pipe from the main to the street line, and charge the water taker for the portion of the line from the street line to the cellar. We put on a stop and waste and charge what it costs.

I think we ought to charge a little more than we do. We charge the bare cost. Being a water company, we make it as favorable for the water taker as possible. For thirty-five cents per foot we think we could do pretty well, on account of the easy digging. Before the rise in galvanized pipe, our services averaged from twenty to twenty-four cents per foot for inch services. That doesn't include the cellar cock, but includes the sidewalk cock.

Mr. George A. Stacy.* When we first started the water works in Marlboro we adopted cement-lined pipe for the services, and used it for perhaps eight or ten years. In that time there was more or less lead pipe used in the plumbing, and from the character of the inside of the pipe and the evidence of its use for ten or twelve years, and as the water for our additional supply that we were about building would be of the same character for generations to come, undoubtedly, I decided to try lead pipe. The wrought-iron pipe at that time had begun to give out in various ways, we had had trouble in the joint, where it rusted back. For the last fifteen years we have used nothing in the city of Marlboro but lead pipe. In all that time there has not been one case of sickness or disturbance in the human body in the city of Marlboro that doctors have laid to the lead pipe. That, to me, was the strongest evidence that lead pipe was a safe pipe for us to use there, knowing that the probability was that the source of supply and the character of the water were going to remain the same. I consider it the cheapest pipe to lay. When you lay it under a pavement, or in streets that you do not care to dig up, if you lay it heavy enough, under circumstances like those in our city, I consider it the best service pipe that is made. I consider

* Superintendent of Water Works, Marlboro, Mass.

the ideal service pipe to be a glass pipe, but they haven't got that very flexible.

If I was going into another place, I should be very careful what service pipe I should adopt. I would experiment five or six or ten years with actual use of the pipe, rather than trust to any analysis. I would rather judge it for myself. Of course we must say that cement pipe is safe, but if we are safe with something better, then let us adopt it. That is the way I look at it, and up to the present time we have won on that issue.

In Marlboro we found that the outside of the cement pipe gave us about as much trouble as the couplings, — the rusting back of the stopcock.

Mr. D. A. Heffernan.* In Milton we have about thirty-nine miles of service pipe, and in 1902 we changed from lead to cement-lined pipe. At that time I should say 75 per cent. of our services were lead pipe, and at that time we were taking Hyde Park water from driven wells, with more or less carbonic acid gas. In the year 1902, our water was condemned, and we had several cases of lead poisoning, — one fatal case, and four or five other cases through the town, — and a suit was brought against the town, and judgment, of course, was rendered for the plaintiff.

At that time, I looked into the service question, looking over the different materials to use, getting in touch with different superintendents and finding out their experience, and finally we decided upon the cement-lined wrought-iron pipe.

The average service is a 1-in. Byers' wrought-iron pipe lined with cement, to $\frac{3}{4}$-in. We line the pipe ourselves in about 14-ft. lengths. We use lead-lined couplings and the ordinary three-quarter flanged connection gooseneck. The average service is about 109 ft. long.

I am opposed to rigid connections. I always believed that there ought to be some allowance there for expansion and contraction. There is the case of running a pipe parallel with another which would cause some strain so that it would be apt to break off. A lead gooseneck allows for a good deal of expansion.

In regard to the inside of the cellar wall, I gave that thorough study and installed everything brass with the cement-lined pipe.

* Superintendent of Water Works, Milton, Mass.

I did not use any wrought-iron fittings at all at the meter. We find we have an absolutely good service, and consider it pays, for if we had had wrought-iron nipples it would be a case of filling up all the time, but by using the brass nipples we have a good clear passage and no corrosion at all in the cellar. The service is laid by the department, from the street main to inside the cellar wall. We use lead couplings. I claim that is a very important feature. Some of the superintendents use the cement-lined coupling. I am thoroughly opposed to it, because I think in making a connection the cement is apt to crumble, and in doing so it gives the water a chance to get in contact with the iron, and to have a chance for the collection of sediment, inside the cellar wall. This pipe is coated with graphite paint, two coats. We line our own pipes; it is done by the department men in about 15-ft. sections. Rosendale cement is used.

Two-inch cast-iron pipe can be used on long distances. We have been using it for twenty-five years, since I have been there, and that pipe has never given us any trouble at all. This cast-iron pipe, I might say, weighs 9 lb. per foot.

Mr. Allen W. Cuddeback.* I am, perhaps, one of those who have had the most experience of anybody in the Association with lead-lined iron pipes. I have been using them for sixteen years, and in perhaps as many thousand services. I am very much in favor of making stiff connections, — straight, solid connections from the main to the house, — and I have yet to have a single one of them break off. One of the principal advantages we find with the straight connection is that during these very cold winters when all of us have service pipes that freeze we can thaw it out in a few minutes. The doubt in my mind as to lead-lined pipe was, in the beginning, whether we could get continuous lead lining, and during the early years, the first eight or ten years of our use, I dug up, each year, two or three connections for examination. And the result of those examinations has led me to believe that in almost all of the cases you get a continuous lead lining if you are careful in setting the pipe up properly. And we have not had to renew any of our lead-lined pipes from choking up by rusting or other cause.

* Engineer and Superintendent Passaic Water Co., Paterson, N. J.

I have renewed thousands and thousands of both lead and galvanized-iron pipes within the last fifteen years, the life of which has been anywhere from twelve to twenty years. I find that lead pipe is attacked by electrolysis as readily as the iron pipe is, and becomes practically rotten and goes to pieces all over.

Mr. George Cassell.* My experience has not been very great with metals other than lead for services. We have used lead pipe in our city ever since the water works were installed. When we first started in, we used what was known as tin-lined lead pipes, but the water acted upon the tin, and the lead was so light that the pressure expanded it and there were a great number of leaks, so that we were forced to remove all of that and start in with pure lead. We use now nothing but $\frac{5}{8}$-in. pipe, $2\frac{1}{2}$ lb.

We used to use a coupling that was soldered on, but do not any more. We use the Anderson method. We used to use a gooseneck to allow the pipe a certain amount of play so that, if there was any motion, it would not break the cock off. Then we ran to the curb cock and put it on with solder just the same as we did the corporation, but now we do not do that; as I said, we use the Anderson method, which I have found to be very good. I have no fault to find with lead pipe, and in my opinion it is as good as any material that we can use. It has given a great deal of satisfaction. It is like all other work, — the material is always blamed where it should be the workmen that should be blamed, and not the material.

I have been forced to make a change, however, for the following reason: Since the fire of 1908 there has been a great deal of building, and when we run a lead pipe into a building — and that is the first thing they call for, because they want the water to use for building purposes — if the building happens to set on the line our method is to run the pipe to the line and push it through one foot for them to connect to. The builders connect to that end and either put on a hose bibb or a stopcock so they can screw a hose on, and they wiggle and they pull and they twist that pipe so that when they get through and the building is ready for occupancy the pipe is either broken or has been patched or is in a weakened condition. We have had a lot of trouble from that, so I was

* Commissioner of Water Works, Chelsea, Mass.

forced to make a change. I looked them all over and made up my mind I would try some of this lead-lined iron. So I got a little of it to try, and I am forced to think that I made a mistake in not using more of it before. I haven't had experience enough with it to talk to any length. I don't know what action electrolysis would have on it. I don't know what action frost would have on it. As to freezing inside, we all know that iron pipe or any pipe made of hard metal that has ice formed inside of it so as to expand will crack quite a ways and you have got to dig down and take out the whole length. With lead pipe we don't have to do that. If good lead pipe of standard thickness is put in properly, you have very little trouble from it. But you are going to have some trouble. But, whatever trouble there is, you can get down to it and remedy it quicker and with less work than you can in the case of the other materials.

Mr. William Naylor.* At Maynard we use cement-lined wrought iron, except that about fifteen years ago the American Woolen Company built something like one hundred and fifty houses and they wanted lead-lined pipe, so the superintendent at that time put it in for them. Now, I find the only trouble with the lead-lined pipe is inside the cellar wall, from the wall to the stop and waste. They rust out just the same as cement-lined pipe does. That is the only trouble so far that I have found with the lead-lined pipe.

My chief trouble with cement-lined pipe also is inside the cellar wall, from the wall to the stop and waste, so I have been putting a coupling on with a bushing and a $\frac{3}{4}$-in. brass nipple and put the stop and waste on that. I believe the coupling is so much heavier than the pipe that it will not rust so quickly, and as it is also cemented on the inside, I believe that it will help a good deal. I believe that an 18-in. or a 2-ft. piece of brass pipe from outside the wall into the cellar would obviate all trouble.

Mr. L. M. Bancroft.† We have been using the lead-lined pipe eighteen or nineteen years and have had no serious trouble with it. We have had trouble from electrolysis where pipes pass under the electric car track, and we have found the iron pipe com-

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* Superintendent of Water Works, Maynard, Mass.

† Superintendent of Water Works, Reading, Mass.

pletely eaten away and the lead pipe left almost intact. It would stand until enough of the iron pipe was eaten away so that there wasn't strength enough in the lead to hold it. We have had one service that we have renewed four different times. We haven't had very much trouble from electrolysis in the last two years. The railway companies have been putting in better bonds, and have made some connections with their return wires, which has improved conditions greatly. We use the gooseneck in making the connection with the main. We have had a little trouble with the lead-lined service, which I presume might happen with a lead service, too; where the cellar had been built and the water turned on for building purposes, the pipe would freeze in the cellar, and then the attempt to thaw it out by building a fire under it would melt the lining and in that way close up the pipe.

I had one service, originally laid with cement-lined pipe, and in a few years it filled up. It was relaid with a lead-lined pipe, and in a few years that filled up. It was then relaid with a galvanized pipe; and that pipe has now been in use about eighteen years and we haven't had any trouble with it.

Mr. W. C. Hawley.* This is a very excellent report, and I think one of the good features of it is that it points out the fact that the particular material for service line is to be determined by the particular conditions. You cannot make any general rule and say any one particular material is the material for general use.

I note, however, that the report says very little about the joints to be used in lead pipe. It has been my experience that that is the chief difficulty with the lead pipe. A wiped joint is a very difficult proposition to handle, especially where those joints may be made by any plumber that happens to come along, and for that reason I have ceased, for some years, to use wiped joints and I am using one of the patented couplings, with excellent satisfaction. In our plant, some twenty-odd years ago, there were a certain number of service lines put in with one of the old-style patent couplings, one which has practically gone out of use. Those couplings are still in use, and we are having very, very little difficulty with them; none, in fact, except where they are disturbed.

Some fifteen or twenty years ago, I had occasion to replace a

* Chief Engineer and General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.

great many galvanized service pipes. Nobody seemed to know whether the old service lines were wrought iron or steel, but many of the old lines which had then been in service ten or fifteen years were still in a very good state of preservation, with very little rust, while many of the lines which had been put in within five or eight years were practically stopped up with rust. There was evidently some great differenece in the material in those service lines. When we get reports from one place that they are using a certain kind of pipe with fine satisfaction, and another place they are using that kind of pipe and not getting results, there may be some difference in the time when those services were put in, and the material of which they were made.

Mr. McKenzie. We use galvanized-iron pipe for our services, and find a slight tendency to rust in the couplings. We have a supply of couplings on hand, and keep them painted on one side with a heavy elastic paint. When a job is put in, those couplings are put in place of those that come on the pipe, and I believe it is going to be a saving, in connection with the life of the service.

Mr. A. L. Sawyer.* In Haverhill we use lead services altogether; that is, up to two-inch. We have taken up services that have been in use fifty or sixty years, and they are in pretty good condition as a general thing. I have been renewing services forty or fifty years old. In regard to cement-lined pipe, I have used cement-lined pipe for twenty years, and have found that cement-lined pipe itself is all right; it is good service pipe, but, after it has been in the ground eighteen or twenty years, the part that goes through the wall, about three feet, say, from the wall, is apt to be corroded. If it could be protected where it goes through the wall, it would last longer, but I think the whole outside of a cement-lined pipe should have some protection, should be painted with something or protected in some way from rust, for I have seen cement-lined pipe, which had been in eighteen or twenty years, where the iron would be all gone, and the cement would be the only thing that would be holding the water. A mere touch, of course, and it is gone. The trouble with corrosion is at the joints, they will corrode; but I think this makes an ideal pipe.

* Water Registrar, Haverhill, Mass.

Mr. J. M. Diven.* Troy, N. Y., has used 1-in. cast-iron pipes, and after these have been in use probably from fifty to eighty years, they are giving trouble by clogging up. I would not recommend cast-iron service, even if it was in the market; in fact, I am taking them all up now. I presume that none are less than fifty years old.

Some further information on the subject of the use of the flange connection instead of the wiped joint, I think, would be of interest in connection with the discussion. I have used them myself about twelve years, and have never had any trouble with them. We have had trouble with poorly wiped joints.

Mr. J. W. Ackerman.† At Auburn, N. Y., we use the flange connection, using 3A lead with brass ferrules, and we have never had one that leaked. Mr. Hawley says the wiped joint is an uncertain factor always. If I have a service pipe that leaks, I am always sure of finding the trouble at the wiped joint.

If a man needs more than a 2-in. service, he is very apt to need considerably more, and we put in a regular standard 4-in. cast-iron pipe, for any connection larger than two inches.

Mr. C. N. Taylor.‡ We find, in towns throughout New England, almost every condition, all kinds of soil, and I have almost always used the lead flange connection and wrought-iron galvanized pipe. I have been doing this for something like twenty years, in many of the cities I have had occasion to look after, and I have had almost no trouble that is due to the action of the galvanized wrought-iron pipe. With that experience, I am inclined to continue to use those materials. It is a pretty good scheme to use material in water-works construction that is almost fool-proof, and that can be built by one not an expert, and which does not require a plumber to connect the joint. We have no fear that the work is not being done properly, the same as you do with the use of a lead-lined or cement-lined pipe. The ordinary piper will put a galvanized pipe together so that you can depend upon it. For small towns, where they are not able to have an equipment, and several men employed constantly, the lead flange

* Superintendent of Water Works, Troy, N. Y.

† Chief Engineer and Superintendent of Water Works, Auburn, N. Y.

‡ Contracting Engineer, Wellesley, Mass.

connection with the galvanized wrought-iron pipe is the best combination that can be used.

MR. W. B. R. MASON.* In Bound Brook, N. J., we have about eight hundred services; every one is a rigid joint. Perhaps our soil is adapted to that kind of a joint. We have no trouble with leaky joints.

MR. S. A. AGNEW.† We use in Scituate a lead flange connection, and strictly wrought-iron pipe. Now, whether the steel pipe is as good as the wrought-iron pipe, I am not prepared to say, but our works are only about fifteen years old, and we have not had time enough to test any one of our services to see whether or not one is going to last as long as the other. One of my chief reasons for using strictly wrought-iron pipe is because I find the use of steel pipe is the cause of profanity by my men. When they get hold of a piece of steel pipe, I find there is a good deal of swearing on the job, and for that reason, if for no other, I use the strictly wrought-iron pipe.

MR. A. A. REIMER.‡ It seems to me that rigid joints are applicable only in places where the service pipes can be run in a straight line. We are dealing with gas, electric conduits, telephone conduits, and there are all sorts of structures in our streets. If there is anything that is flexible, let us use it and keep out of the way as much as we can. That is the reason for my being in favor of the flexible joint, rather than a solid stiff joint from the pipe in, — to keep the street as free as possible from fixed structures so that the structures that cannot possibly go otherwise can have a little chance to go through.

In East Orange we use a flexible connection. In fact, we run the flexible pipe all the way to the curb line, and from there we change to a wrought-iron pipe, one inch, galvanized, all the way through to the cellar lines. We have no trouble with our wiped joints, and we have thousands of them throughout the city, about 8 500 connections, all told. We make our own wiped joints, regularly, and don't employ a high-grade plumber in doing it, either. We have a man who has come up from the trenches in

* Superintendent of Water Works, Bound Brook, N. J.

† Superintendent Water Works, Scituate, Mass.

‡ Engineer Water Department, East Orange, N. J.

our work, and has learned to wipe the joints, and does it regularly, and they stand up successfully.

Mr. C. D. Sharpe.* We have now in the Putnam plant 1 070 services, counting all sizes. Our ordinary house service is three-quarter inch in size, although services of sixty or more feet in length are one inch, in many cases. In making the connection, the nipple is wiped on to fifteen inches of 3-lb. lead pipe, with a female solder nipple on the other end, which makes a gooseneck about 20 in. long. The service pipe is screwed into the gooseneck, and just back of the curb line we put in a curb cock, with a Bingham and Taylor curb box over it. The pipe is carried through the cellar wall four inches or more, and a stop and waste put on, with a union on the cellar end.

At the inception of the water company we used enameled wrought-iron pipe, made by the Providence Enameled Pipe Company, and it certainly was good pipe, quite a lot of it still being in use. As time went on, we thought the quality was sacrificed on the reputation made, and quit the use of it and took up lead-lined pipe in 1908 and 1909. We have found this to wear very well, and have replaced but few of the services laid with it; but we had some trouble making the joints, as the lead would be loose, in short pieces. This has been remedied since, so the lead cannot be separated from the iron, excepting by heat.

Since using the lead-lined we have used wrought-iron galvanized pipe with fairly good success. We have had more or less trouble with pipes filling up, where iron and brass came together, caused, I suppose, by galvanic action of the two metals. By letting the pipe protrude through the wall four or five inches, it gives a chance to cut another thread, if the first rusts off, and I have noticed that in some cellars the pipe deteriorates much more rapidly than in others.

Our brass goods have always been the same style, viz., Newport stops, Fitchburg stop and wastes, and a heavy corporation cock, and all full size, round-way opening. We have not varied from this style, for I have appreciated the fact that when you dig up the main you know what you are going to find and have more like them if they need replacing.

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* Superintendent City Water Department, Putnam, Conn.

I also appreciate the efforts that this Association is making to standardize different things in common use, and I hope to see the day when $\frac{3}{4}$-in. meters, and less sizes, of all makes, shall all have the same size spuds and threads and all be the same length, so that one can send out a man to change a meter, carrying the new meter and two wrenches, rather than carrying couplings, short nipples, and die stock and cutter, for fear it will be either too long or too short.

Mr. C. L. Baker.* About a year after I took charge of the Abington Water Works, I changed from cement-lined to galvanized wrought-iron. The trouble I found with the cement-lined pipe was that it wasn't properly lined. I had a good deal of trouble for the first year. I presume it was the fault of the man employed to line the pipe. The pipe was unevenly lined, and it flaked off. There were places where it wouldn't be more than one-eighth of an inch thick, and the water would get under it and of course throw it off.

The couplings were unlined, and they would fill with rust and then the water would get under the cement next to the joints and it would be thrown off, and plug up the pipe.

I use galvanized wrought-iron pipe, the best I can buy, because of the fact that I know of some places where there was steel put in previous to my taking charge of the work which lasted only five years. I use a 1-in. pipe, and in case of two-family houses I use a 1-in. corporation.

Mr. Horace Kingman.† In Brockton we have been using cement-lined pipes for pretty nearly since the works started, — thirty-six years ago. We now use nothing but galvanized wrought-iron, cement lined.

I don't think you are sure of getting as uniform pipe in steel pipe as you are in wrought iron. There is a difference in cutting threads if you use commercial dies. You can have dies made that will cut steel and iron equally well. There is no difficulty that way, — only you have got to use a different die for cutting steel than you do for iron.

In lining the pipe we first bore the pipe, drive a cutter or plug

* Superintendent of Water Works, Abington, Mass.

† Superintendent of Water Works, Brockton, Mass.

through to take the burrs out, and then we change the coupling over, and line as they ordinarily do. Of course, it is possible to have the pipe already cored or bored if you want to, but when we have had bids we have found that we could do it cheaper ourselves,— possibly not so well but well enough, and cheaper.

The couplings are turned so that we may be sure that they start on the pipe right, and then there is a nipple put in the other end of the coupling of the same size, and the lining run up to that.

Mr. A. F. Hart.* I have noted that with each of the different kinds of service pipes that we have in Saugus there seems to be some trouble, and it is only a question of picking out the one that has the least trouble. Up to four years ago, we had used cement-lined pipe, lead-lined pipe and some galvanized. The cement flaked off and bothered a great deal. It may be that was in the fault of the construction, — I don't know. The lead-lined pipe corroded on the outside very badly. We had some that had been in only about four years and we had to take it out on account of corrosion from the outside. That may be due to the soil. We now lay nothing smaller than 1-in. services.

We now use enameled pipe. The pipe is dipped two or three times, allowed to dry each time, run into an oven and baked, and when it comes out it is almost impossible to scar it even with a wrench; in bending, it never flakes or chips off. It is perfectly elastic. We have tested it in as many different ways as we could, to get as nearly the effect of years as it was possible to, and compared it with all the other brands that we used, and it certainly showed the brightest of anything.

It costs ten cents a foot, landed in Saugus. I buy Byers' 1-in. black pipe, and have it enameled. It comes back just as smooth inside as a piece of glass. It looks like the enamel they put electric wire into, but the coating is much thicker and the preparation is different.

I have had it three years. That, of course, is a very short time for pipe, but it is all just as bright as when it was put in. Of course, enameled pipe is not a new thing, but we think this an improvement over the old type of enamel.

* Superintendent of Water Works, Saugus, Mass.

Mr. George H. Finneran.* Those of us who are concerned with the sizes of the pipes ought, in my opinion, to examine into the conditions very carefully when application is made for a supply, in order to determine the exact requirements and grant no larger size than is really required, — because of the consequences.

The consequences of over-sized pipes are several and expensive. First of all, the larger the pipe, the larger and more costly the meter; and the repairs of a larger pipe are more costly than those of a smaller one; the loss of water from a leak or a break is greater, and the damage which is apt to result to property is also greater usually. More important than all is, as Mr. McInnes graphically described in his paper on the Salem fire,† in the case of a conflagration where a building collapses and the pipe is broken off, the loss of water there brings the pressure down in a street to a point where it handicaps the fire department.

Mr. J. C. Chase.‡ My first experience with service pipes was in the use of cement-lined; this was abandoned to a certain extent on account of the trouble of putting them in. It is an ideal pipe if properly made and properly laid, but a difficult one to get labor to handle in the right way. Another vulnerable point was that they were not careful about getting an intimate connection of the cement at the couplings, and very soon it would corrode and stop the flow. Then several kinds of protected pipes, like rubberoid and tar-coated, were in use. I think that the lead pipe is the ideal pipe if you can get rid of the sentiment against it, and I think in nine cases out of ten it is nothing but a matter of sentiment, as being deleterious. But if you are not going to use that, you have got to determine the character of the water and take the next best thing.

Mr. T. G. Hazard, Jr.§ We have had occasion, recently, to set back some of our service boxes, owing to the fact that when they were first put in there were no curb lines established. Our services were all lead. We lay our services to the curb line, and the householder ordinarily carries a galvanized-iron pipe from the

* General Foreman, Water Service, Boston, Mass.

† Journal N. E. W. W. A., XXIX, 94.

‡ Derry Village, N. H.

§ Civil Engineer, Narragansett Pier, R. I.

curb line to the house. Our method of extending these services is to dig up the old curb box and cut off the galvanized-iron pipe, and extend our service one or two feet, or whatever it is necessary. We find in a great many cases that these galvanized-iron pipes are so rusted up that it is impossible to cut a thread on them, they are so far gone.

Mr. McBride.* We found that a cement-lined pipe will do very good work, but that the joints are likely to be troublesome. Of course when you line the pipe and the coupling together, and then cut back the cement as has been described, for five or six threads, you try to keep that cement flush and square with the center so that when the pipe comes in it will meet. But it is always guesswork; of course we cannot see on the inside of it.

We took some short pieces of pipe, about a foot long, so that we could look into them, and before putting them together we put some cement in the coupling. We used Portland cement in that case. Then we had a rubber ball on the end of a wire which we put into the pipe beyond where we were working, and screwed the pipe up tight, — the idea being that the cement would squeeze out into the thread and between the two ends of the pipe, out into the inner pipe. Then, after we had finished with that, we drew the ball forward, and that gave a wipe of cement which closed up the crack completely. Then we pushed the ball back once, and drew it out with the residue of cement. After a day or two, we cut the pipe very close to the coupling, and we found that we had an absolute surface of cement right across. I thought this might be interesting, because I haven't heard it spoken of before. I don't know that it has ever been tried. We have pipe supplied to twenty-two feet of length, although we have it down to fifteen. If you are using that length of pipe, you can take a wire with a rubber ball and then put in your cement and draw it through. I think you will find in nearly every case that your cement will be in there and you will have a perfectly joined cement pipe.

Mr. A. E. Martin.† Springfield, Mass., uses rigid joints, and has for thirteen years, and I don't know how long before. When I went there, I found that they had adopted that plan.

* Of the Macbee Cement-Lined Pipe Co., Boston, Mass.
† Superintendent of Water Works, Springfield, Mass.

That was thirteen years ago. We never have any more trouble with the rigid joints than we used to have in a smaller place with lead connections. I consider it a success.

I think that the general opinion of any one who taps a water pipe is that it is a good deal better to push the corporation in a quarter or half inch into the pipe than it is to leave it flush. You are going to have a lot of trouble if you leave it flush absolutely. We once in a while find, in my experience, a corporation that is tapped part way in, not quite through. The hole, of course, is tapped through and we get a complaint that they can't get any water. I have in mind one that happened about three months ago. The service pipe had been in about twenty-one years, by the way, and we knew from experience that it was probably filled up some; but if we had dug up the main and cleaned that corporation, we could have prolonged the life of that service pipe I don't know how many years. In putting in the new service we found the corporation was plugged up.

In regard to the corporation cocks which extend into the pipes when a pipe cleaner is used, I would say that I have asked that question of the pipe cleaning manufacturers and they say there is absolutely no danger,— the cleaner will pass by in every case.

Mr. G. E. Winslow.* In 1884 or 1885 I used cement-lined pipe, and to protect the coupling I put a piece of pipe perhaps fifteen or eighteen inches long into it, with a couple of threads. Then I pushed the cement into it, and I had two cones, one eleven or twelve inches long, and another one back of that; one to go to the center, the other as a follower. In pulling that through, the cement would come through into this coupling and against the piece of pipe that was left. That left the coupling lined with cement. I had never taken any of that pipe out until this last summer, when I had occasion to change the meter, and the stopcock on the end had to be removed. I had a piece about four feet long outside, because I had seen that the pipes inside the cellars, nearer the stopcocks, and more especially that exposed to the air and dampness, would rust more or less. In some cases I have seen pipe put through that way and painted, but mine was not painted. It broke off, so they had to dig out a little way,

* Waltham, Mass.

and they took off this piece of pipe and the coupling was there lined in the way I speak of, with no rust whatever. So I thought that as it had been lying there for twenty-nine years, and the pipe was in good condition, my theory was all right.

Mr. D. N. Tower.* In Cohasset we use galvanized iron in most cases, but lead pipe if near salt water. At first we put in a few cement-lined services, but we are so near salt water I was afraid the pipes would rust through from the outside, as they were not galvanized. There is trouble with corrosion on the outside where the pipe is near salt water or laid in ashes. I am beginning to have trouble inside the cellar where the shut-off screws on, where the thread is eaten away by the action on the metal. At the beginning I didn't allow the services to extend through the wall far enough to cut a new thread, so that necessitated digging up outside and putting on a piece; so now I am careful to let the pipe extend through far enough so that I can put on a new thread. Then I put on a brass nipple back of the shut-off.

We have always used lead connections, as it is so much easier to change the direction of the service.

I made a mistake when our mains were laid in an unusually dry summer by laying them so deep that the ground water in some cases was above the main. I have to dig to get down to the tap, and bend the lead connection up to the service.

I have, I suppose, more shutting off to do than most places on account of the summer people. I found that it is better to set my shut-off cock on the lead connection, as shutting off and turning on every year starts them leaking, and it saves digging up the ground in two places by having the shut-off and corporation at one place.

Mr. G. T. Staples.† The works in Dedham were constructed in 1882, and we laid common enamel pipe. Of course, it filled up and leaked at the couplings, and the threads rotted off and we had a good deal of trouble. Then we adopted cement-lined pipe. We have had some trouble, but most of our trouble has been with the goosenecks. We put in a brass nipple that was very light, and our water is very hard on brass and it leaks through it.

* Superintendent of Water Works, Cohasset, Mass.

† Superintendent of Water Works, Dedham, Mass.

We use the Rosendale cement for lining. That is what they started before I came there and I kept on using the same thing. I never had any trouble with it. The couplings we line with lead. There is one advantage with the lead couplings; the lining gets in between the two pipes and when they are screwed up and protects the whole thing and keeps it from leaking. It is just the same as using a lead washer. We use Byers' wrought-iron galvanized pipe, cement lined. I have tried all the other pipes, but they don't seem to run uniform.

In regard to bending cement-lined pipe, I agree with Mr. Forbes. I have bent pipe to right angles and then sawed it in halves with a hack saw and the cement was just as good as ever. I would not have believed it until I had done it.

Mr. G. F. Merrill.* Our plant at Greenfield has been in since 1872. The original service pipes were of wrought iron. Since 1907 we have used galvanized pipe, strictly wrought iron. Previous to 1907 all the connections were made rigid, with no gooseneck at the main. I took a service out this last season that has probably been in since the works were installed.

We have had a good many leaks with the rigid connections. It is hard to account for all of them. Quite often in the fall of the year, perhaps about the middle of December, we have more or less trouble of that kind. It seems to me it is more pronounced at that season of the year, when the frost is getting into the ground, or perhaps a change in temperature in the water.

It used to be customary to tap the main on the top with a rigid connection, — tap it exactly on the top and use an elbow That elbow would be turned in the direction the pipe was laid, of course, and any strain on the service pipe near the main would break the cock. A good many troubles of that kind we found were caused by excavation of trenches near the main, either for sewers or gas or other sort of work. We invariably found that if the back filling was not very carefully done, when that filling settled down its weight would break off the cock on the main. Since we have adopted the lead gooseneck we have avoided that almost wholly. The gooseneck we now use is one that we make ourselves. We use lead flange brass fittings, similar to the Mueller lead flange fitting, and buy a lead pipe and make it up at the shop. The

* Superintendent of Water Works, Greenfield, Mass.

gooseneck is made with a tool that we get up ourselves. It simply turns out the lead and flanges it down. We find a man can make them very rapidly on a machine of that kind.

Once I used some of the goosenecks that were made with the soldered nipple and a union at the end that attaches on the main. They were supposed to be sweated in, but we had some trouble with them when excavating near the main; the solder being somewhat brittle, if we strained a pipe it would leak at that point. We have better results with the lead flange gooseneck because it is absolutely solid right up to the base of the union, and when it is made up tight, there can be quite a little movement of the service pipe without starting any leak.

We use a three-quarter-inch service, but I think the use of a one-inch service would increase the life very materially. The difficulty would be the little additional cost. Most, or a good many, new buildings are built by contractors who take the whole contract for the building and the water supply from the main, and they look pretty closely at every penny that is expended on the water service.

At present, our rules require that we lay the service to the street line, and where the owner desires it we lay it up to the cellar wall. In most cases they ask us to lay it up to the cellar wall.

I think all water works should have complete control of the service right up to the meter. An illustration of that is perhaps a condition that I found in my services when I first went to Greenfield. At that time the services were owned by the owners of the property and paid for to the main. It had been customary, ever since the works were established, to allow every owner to put in his own service. He either employed a plumber or employed laborers and did his own plumbing. The water department furnished the curb cock and sidewalk box, and they set the boxes promiscuously, sometimes inside their own land, sometimes in the street, and the services were put in without much system. Another feature that is bad, particularly with contractors who are building a house to sell,—they seldom excavate more than two feet deep for the service, which causes a lot of trouble about freezing, or else you have got a condition where you have to allow the water to run continually to prevent it from freezing.

I think one good feature of using the lead gooseneck is being able to drop your pipe quickly to get below the danger of freezing, and the other feature is quite a saving in time for the man connecting a pipe up in the street.

I believe we shall adopt the cement-lined pipe as soon as we have facilities in the shop for lining it.

MR. P. R. SANDERS.* At Concord, N. H., we have always used black wrought-iron pipe, cement lined. Our main trouble has been where the corporation was screwed on to the service pipe at the main, and also at the curb valve. We have been troubled with corrosion forming from the iron right in to the curb valve, and also on the female connection on the corporation. The same thing would happen in the cellar. The cement-lined pipe has worked so well with us that it seemed to me that the thing to do was to get something that would do away with that corrosion as much as possible. For the past two years we have been using a thimble that we put inside, after reaming out the cement a little bit, and I think this is going to stop the trouble. The thing you have got to do, in my opinion, is to stop the water from getting at the end of the iron pipe. If you can stop that, you are stopping your pipe from rusting away from the inside back to the valve.

We use lined fittings exclusively. We originally used a plain coupling, that is, the coupling that ordinarily comes with the pipe, but we have substituted driven pipe couplings, because very often we find the ends so battered that it is almost impossible to catch a thread. With the driven couplings we never have any trouble.

We have been lining our pipes with Portland cement for the last four or five years and have no trouble.

The property owner looks after his own service pipe from the street line. As a general rule, he will put in galvanized pipe of the size that we use. It is not laid under the supervision of the water department. The only thing we insist upon is that the owner's pipe shall be laid at the proper depth.

MR. L. R. DUNN.† The old Revere Water Company, which

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* Superintendent of Water Works, Concord, N. H.

† Superintendent Water Department, Winthrop, Mass.

laid the main pipe, installed cement-lined services in 1885. I went to work for the department in 1890. We didn't begin to get any trouble with the cement-lined services until after we began to use the Metropolitan water in 1898. Then we began to have trouble with the fittings on the cement-lined pipe. The water company used galvanized fittings, and they became packed completely full of rust. We had no trouble with the cement-lined pipe, because after we removed the fittings, the pipe was apparently all right on the inside, but wherever we used those galvanized fittings, we found trouble.

After the year 1900 the company stopped making the cement-lined pipe and they used galvanized pipe and got into worse trouble than before. In 1909 we abandoned the use of galvanized pipe, and since that time have been using nothing but lead.

Mr. H. P. Plimpton.* In 1896, Walpole used three-quarter-inch lead-lined pipe and had trouble at once. The pipe plugged by water getting under the lining. We now use for services plain wrought-iron pipe lined with Portland cement and beach sand. More or less galvanized pipe is used by the owners; and while we do not advise its use, we cannot prevent it, as we allow takers to put in their own services, but if they have any trouble from it, they pay for it in the end.

Different cements require different amounts of sand. We are very particular in the way the pipe is handled. We don't allow a pipe to be bent at all, and don't allow a man to carry one length of pipe on the team, but tie three or four of them together so that they will not bend.

Wherever we have to cut the pipe and use a fitting, we use a composition coupling or union. We haven't had any trouble from pipe corroding around the fittings.

We have trouble with our pipe rusting out through the cellar wall, and have found no way to remedy it except by putting in a three-foot piece of brass pipe, and that costs too much for most people. I put it into my own house and I would like to put it into all. I don't believe it is possible to prevent iron pipes rusting in the cellar.

* Superintendent Water Works, Walpole, Mass.

Mr. Frank B. Wilkins.* In Milford we have used cement-lined pipe for twenty-four years, and personally I have for fifteen years, and we have had very little trouble with it. Our town, while small, doesn't wish for anything else but the cement-lined pipe. We use the gooseneck. But as far as lead pipe or lead-lined pipe is concerned, they would not tolerate it a minute in the town. Our goosenecks are only twenty inches long, but some object to even that amount of lead being put into the system. We have very good success. They have been frozen up during different winters, but they have not to any extent given us trouble by opening up so as to give us a leak. In many cases they have thawed themselves out and have run for years afterward.

Mr. F. L. Fuller.† The works at Wellesley were built something over thirty years ago, and at that time of course there was not as much information as there is at present. We used tarred iron pipe, and it lasted about a dozen years, and then became filled with corrosion and rust. We then adopted cement-lined pipe, and have used it ever since with excellent results. We have services that have been in twenty years that are just as good, apparently, to-day as they ever were, and when for any reason a piece of this pipe is removed, it always appears clean, and there has been very little trouble with the corrosion on the outside of the pipe.

So it has seemed to me that there was no better pipe than the cement-lined pipe. As has been said, it should be carefully made, because it must be properly and thoroughly filled, and proper cement must be used, and care must be used in handling it. All those things contribute towards a good pipe, but it seems to me it would pay for any department to use this care in making their pipe and laying it, because when a service pipe is once in, in good condition, it is there to stay for a good many years.

Mr. Patrick Gear.‡ The service trouble that the gentlemen have spoken of is the same in Holyoke. We have all kinds of services there, and all kinds of pipe.

This week we have been taking out some service pipe that has

* Superintendent of Water Works, Milford, N. H.

† Civil Engineer, Boston, Mass.

‡ Superintendent of Water Works, Holyoke, Mass.

been in for forty years, owing to the repaving of a street. I couldn't tell whether it was galvanized pipe, or what kind of pipe it was, but it is in pretty good condition to-day on the outside. In 1892-93 they used to tap the pipe and put in a short brass nipple about six inches long, and screw a stopcock on that. We found that most of these are worn out, so we take them out.

Whether the service pipe is a galvanized pipe, or a lead-lined pipe, or a common iron pipe, with any coating on the inside or the outside, when you cut a thread in it you will have the iron exposed. The only place that the service pipes give way is where they are screwed into the stopcock. We use lead-lined pipe almost entirely, but we use some galvanized. We have some pipe that has been in for forty years and has given good service, and we have had the same kind of pipe in there for twenty years and then have had to renew it.

Every time we find a gooseneck, we take it out. Our goosenecks that we had in years gone by were put in probably around 1880, and we have had a lot of trouble with them. They used to have a white paint on them, and we had more trouble with that connection than any other connection we had. Then they used to make what they called tinkers' joints, and some of them gave a good connection.

As far as our city is concerned, we do not have any rock or anything to contend with. The telephone people and the gas people come along, and they put their meter or their pipe where they want to, but the water man has to take what he can get. In going into a building they say: "We will have the coal bin here, and the stopcock will be in the coal bin, and if it breaks, shut it off in the street." The water man is the only one who does not get any consideration at all from the man who is building the house. The gas man will have his meter up near the window, and the water man has to go down under the stairs with his meter, if he has one.

We have done away with all three-quarter services. We take the service from the curb to the cellar. The old-fashioned stop and waste that they have in the cellar, that a woman could never shut off, we have done away with, and we now use a wall valve. We put in a plugged tee, so if we have any trouble we take out

the plug and run the machine through and clean it, with a rigid connection clear to the pipe. We don't let any plumber interfere from the main to the cellar.

Mr. R. S. Weston.* I have had very little experience in laying service pipes. I have had considerable experience, however, in protecting them from corrosion. There now seems to be a universal belief in the use of three kinds of pipe, cement-lined iron, galvanized or zinc-lined iron, and lead. I want to emphasize what Mr. Hawley has said, that it is the kind of water that should determine the service pipe. There is no reason in the world why, with a fairly low colored surface water, one should not use galvanized iron, a good grade of wrought iron, or a good grade of steel if he wishes, because you can have good iron and bad iron and good steel and bad steel. Bad iron is far worse than bad steel.

There is also no reason why you should not use lead pipe, where the water forms a protective coating on the inside of the lead. In all other cases, I think the cement-lined pipe ought to be used. I am speaking now from the standpoint of the quality of the water furnished to the service.

A rather peculiar case came to my attention three years ago. The town, which had suffered somewhat from lead poisoning, put in a filter; changed from a ground water supply to a filtered surface water supply. The surface water soon accumulated organic matter enough in the filter so that the water coming through the filter corroded the lead pipe far more than the ground water did before. The remedy in that case was to put lime in the water, and the corrosion was reduced to practically nothing. The reason, of course, for corrosion is acid, and where water is filled with carbonic acid or vegetable acid, the plain iron must be protected by cement or lead, or lead pipe must be used. I have never heard any superintendent speak of any trouble because of well-made cement-lined pipe.

I should like to emphasize one thing that Mr. Stacy has said, regarding the inadvisability of placing too much reliance on laboratory tests of pipe with the water in question. I know of one case where a water company is being seriously embarrassed

* Of Weston & Sampson, Consulting Engineers, Boston.

because the water attacks the lead pipe. And there is one case in this city in particular where the lead poisoning was so severe that the blue lines appeared on the gums, and lead appeared in the secretions, and all the other symptoms of lead poisoning occurred. Yet that water when tested in a bottle for six months showed about a third the capacity for absorbing lead as did the Metropolitan water, and we know that the Metropolitan water has no great capacity for attacking lead. Therefore I wish to emphasize Mr. Stacy's remark that you must take the physical character of the water into consideration, as well as its effect in bottle experiments.

Mr. C. D. Howard.* I may say that most of the service pipe in use in New Hampshire is galvanized iron. Quite a number of supplies are, however, delivered through cement-lined pipe. There is considerable complaint as to the durability of the galvanized-iron pipe, and we very frequently have occasion to suggest the use of cement-lined as calculated to be more satisfactory in such cases. I have of late tried to gain information as to the availability of some brand of pure iron pipe, but such does not seem to be on the market.

The city of Manchester uses lead-lined pipe. There is still quite a good deal of plain lead in use, as well as some tin-lined lead, although the latter is not being installed very much nowadays.

We have always made a practice of determining the lead in every sample of lead-conducted water submitted to the laboratory. As a result of our reports, a very great many of the older private supply systems have been changed over to iron. A great many cases have been encountered where this water showed 0.05 parts per 100 000 up, and in a great many cases where the analysis showed less metal than this there seems to have been pretty definite clinical symptoms of lead poisoning in one or more members of the family. Now and then these symptoms have been confirmed by the urine examination. At the same time, we have never thus far attempted to collect and arrange these cases in an investigative way. In many instances, of course, there is room for considerable question as to whether or not lead is actually responsible for the symptoms noted, it being but natural for the

* Chemist, State Board of Health, Concord, N. H.

attending physician to invoke a scapegoat of this character when the indications were otherwise obscure. At the same time I am satisfied that there has been a good deal of health impairment in the past due to the use of water containing small amounts of lead, and I am convinced of the desirability of the abandonment of this variety of service pipe.

Mr. F. N. Speller. The conditions which influence corrosion of services are radically different on the inside and outside, and require, therefore, different treatment to secure the maximum service. These protective measures should be designed to suit water and soil conditions, as previous speakers have pointed out.

In considering outside corrosion by itself, it seems that the long experience of gas companies should be of practical value. The usual practice is to use a bituminous paint, preferably applied on a priming coat of coal tar in benzol, or this reinforced with one or two layers of coarse cotton fabric saturated with asphalt or coal-tar pitch, tightly wound spirally on the pipe. In particularly bad places, a rough wooden box may be built around the pipe and filled in with cement concrete thoroughly worked. Most gas services, however, receive very little protection. It would seem of practical advantage for local gas and water men to get together on the question of what pipe protection is needed for their particular locality, as the conditions are identical. It will probably be found that protection will only be needed on a small proportion of the lines after a thorough survey of the district is made. The system of wrapping the pipe in saturated fabric is used quite extensively out West, on water and gas lines. The expense of this coating is about one cent per foot per inch of diameter.

The large majority of gas and oil companies now use steel pipe, having found by careful observation in comparison with wrought iron that the service is at least as good. The reference given below to this subject in the proceedings of the American Gas Institute may be interesting to water-works superintendents who are looking for light on this question of iron versus steel.*

A recent analysis of pipe being purchased by gas companies in

* Proceedings of the American Gas Institute, Vol. 3, pp. 265, 274; Vol. 6, Part 1, pp. 318, 348, 351, and 357; Vol. 8, Part 2, pp. 145, 151, 191, 212, 216, 223, and 259; Vol. 9, p. 1065.

105 localities in New England showed the following, which I believe is representative of the present trend. While there are no figures on record, it is safe to say that the per cent. of wrought iron used ten years ago was very much greater.

		Per Cent.
Those using steel pipe exclusively	75	71.42
Those using steel and wrought iron	13	12.38
Those using wrought iron exclusively	15	14.28
Unknown	2	

Extract of paper by H. L. Rice, from abstract entitled, "Installation of Mains and Pipe Lines, Steel and Wrought Iron," Vol. 8, p. 146:

"The question of wrought iron as against steel seems to come down to the relative corrosion, and the consensus of opinion of a number of authorities quoted seems to be that there is little or nothing to choose between the two."

Taking the country as a whole, the official records of the American Iron and Steel Institute show that about ninety per cent. of the oil and gas pipe is steel. (See Bulletin No. 3, American Iron and Steel Institute, 1917.)

As to internal corrosion, it has been well brought out in previous discussion of your committee's report that this depends principally upon the character of the water. New pipe carrying filtered water is subject to comparatively severe conditions, as the natural protection obtained from the organic matter and silt deposited from unfiltered water is lacking. I was not disappointed, in listening to the discussion, to find there were still a few in New England who favored wrought iron, but I did expect to hear more details as to the basis for such opinions. The subject of corrosion involves so many factors that it has been found unsafe and misleading to depend on isolated experiences other than comparisons in service where both materials have been put in the lines together at the same time. The identity of the material should be determined by some one accustomed to making tests of iron and steel, for it frequently happens that what is taken for steel pipe turns out to be wrought iron, and vice versa. Judging by some of the experiences related, it is surprising that any money should

be wasted on coating wrought-iron pipe for service lines. I am now connected with a company which had its beginning in making wrought-iron pipe in Boston about fifty years ago. Probably this company is responsible for some of this good old material which has been fortunate enough to survive, and also for a good deal more that has disappeared due to less favorable conditions. We were never able to connect long life with any particular mix of iron, but did finally determine beyond a question or doubt that steel could be made just as durable as wrought iron. This took a generation of experience. Most of the comparative tests of wrought iron and steel have been made with hot domestic water supply, where the rate of corrosion is much more rapid. More than one hundred service tests have been run by placing several samples of different kinds of pipe in the same line and examining the inside of these pipes after a few years or after the line started to fail. All who have made such tests agree that the difference was very small — usually, however, in favor of the steel pipe. There is no apparent reason why the same conclusions would not hold good, using the same water unheated.

One reason for the opinion which is held by some New England men on this question of pipe is probably due to the lack of a standard weight of pipe. Until a few years ago, steel pipe was made in various weights for various purposes, and substitution of lighter weights was easy. Now, to prevent this, all wrought-iron and steel pipe is made full weight. When steel pipe was first made, only a few of the mills had facilities to make the special quality of uniform soft steel required to give the best results. Many attempted to make pipe of steel purchased on the open market, which is usually very unsatisfactory.

There is a larger proportion of wrought iron in use in New England than in any other locality, but the figures which I have given in the early part of this discussion indicate that the same tendency prevails in New England, for ten years ago the spirit of reverence for what is old and tried was so strong that the per cent. of steel pipe in use was very much smaller.

So I would suggest, if you have strong opinions on this question, to look over your evidence and determine whether your opinion is based on comparative service under like conditions and on enough instances to be fairly representative.

The following records compiled by the American Iron and Steel Institute illustrate the trend of the times.

PRODUCTION OF IRON AND STEEL SKELP IN THE UNITED STATES.

Year.	Iron.	Steel.	Total.	Per Cent. Iron.	Per Cent. Steel.
1905	452 797	983 198	1 435 995	31.5	68.5
1906	391 517	1 137 068	1 528 585	25.7	74.3
1907	444 536	1 358 091	1 802 627	24.6	75.4
1908	297 049	853 534	1 150 583	25.8	74.2
1909	370 151	1 663 230	2 033 381	18.2	81.8
1910	350 578	1 477 616	1 828 194	19.2	80.8
1911	322 397	1 658 276	1 980 673	16.3	83.7
1912	327 012	2 119 804	2 446 816	13.3	86.7
1913	312 746	2 189 218	2 501 964	12.5	87.5
1914	264 340	1 718 091	1 982 431	13.3	86.7
1915	262 198	2 037 266	2 299 464	11.4	88.6

MR. JAMES ASTON.* I am here as an advocate of the use of wrought iron. Mr. Speller speaks about many tests disclosing the fact that steel is just as good as wrought iron. He says also that we should not condemn some of the earlier installations, because the steel at that time was not as good, perhaps, as the steel which has been made to-day. I think there has been progress made in the quality of steel by the National Tube Company, but on the other hand I think it is unfair for Mr. Speller in the next breath to refer to tests of wrought iron and steel, and then to condemn wrought iron as a class, because we can show conclusively that a large part of this wrought iron is not the article in the true sense of the word. It is an adulterated material. Therefore, in comparing wrought iron with steel, he may be condemning the poorer quality of the material.

It is surprising how much of the wrought iron which is on the market to-day is an actually adulterated material in every sense of the word. The effort to get into competition with steel, or the effort to get under the other man making wrought iron, has led to the use of scrap, which is very heterogeneous, even though there is some selection. Then there is the deliberate use of steel mixtures, which remain as such in the final product, and give a

* Metallurgical Engineer, Pittsburg, Pa.

decidedly heterogeneous material, which is not wrought iron in any sense of the word.

I am just as firm an advocate as Mr. Speller of the galvanized product, because the protective coating is certainly worth something. We believe galvanized wrought iron is superior to galvanized steel. So far as the coating itself goes, the character is the same in both cases, but in the case of wought iron, we have the advantage, we claim, that there is an initial roughness to the material which gives a greater penetration to the coat, and a greater thickness to the coat. So, from the standpoint of the like size pipe, wrought iron has a heavier coating than the steel pipe.

I want to speak a little bit from the standpoint of whether the pretty widespread faith in wrought iron is justified, and why should wrought iron get any black eye at all? I think it is a pretty unanimous opinion that pipe which was made fifty or forty or thirty years ago has set a standard which we are all striving to reach to-day. The steel man sets that up as a standard towards which he is striving in the manufacture of his material. There seems to be no question about that old-time material and its quality.

I wish to speak very briefly with regard to the protective influence of slag, because I really and firmly believe, after a number of years' study of the corrosion problem, that much of the merit which wrought iron has in comparison with steel is due to the slag which is present in the former. Both products are the result of the refining of crude pig iron, and both of them during the refining have slags formed which are silicates of iron, materials of a glassy nature. Steel in the finished product has none of this slag, because in the finishing operation the material is fluid, and consequently any slag floats to the surface and comes off.

In the manufacture of wrought iron, on the other hand, the furnace-finishing temperatures are not high enough to have the metal in a fluid condition; consequently, the slag is trapped in the metal, about the same as water would be held in a sponge. Just as you can't get all of the water out of a sponge by squeezing, so you can't get all of this slag out of the puddle ball. This slag is an iron silicate which, so far as its corrosive nature is concerned, is immune from attack under ordinary conditions. The amount of

the slag is about two per cent. by weight, or, to put it in a little better fashion, it is probably six per cent. by volume. The contention is generally made by those who oppose wrought iron that that quantity of slag is altogether too small to offer any resistance or obstruction to corrosive attack. Now, I combat that contention. The effectiveness of any barrier does not depend entirely on its quantity, but it depends upon its manner of distribution. The slag which exists in wrought iron is originally in small globules, which, under the forces that are exerted in the rolls, are elongated into threads, or better, and more generally, in the form of ribbons, in which the lengthwise direction corresponds to the length of the pipe, the width corresponds to the circumference of the pipe, and the thickness corresponds to the thickness of the pipe. By actual count, the number of these slag filaments is from four hundred thousand or five hundred thousand to probably a million per square inch. In other words, they are probably not over one five-hundredth to one one-thousandth of an inch apart in the width of material, and about the same distance apart in the thickness of the metal. Ideally, they are scattered in a uniform distribution.

What is the effect of that slag in retarding corrosion? There is a lessened surface, probably six per cent. of lessened surface to the corrosive attack. Second, as the attack proceeds, it is the iron which is going to be corroded. As the result, iron oxide or iron hydrate will be formed, which we call rust. But it has to stop, for as soon as this corrosion penetrates a short distance, it will strike one of the slag barriers, and the more the iron tends to corrode away, the more and more of these inert slag barriers it exposes to the attack. We also have, of course, the obstruction of the lengthened path through the material because of the barrier action. It might be said that the argument is rather far-fetched, yet we grant that very thing is the mechanism by which cast iron owes whatever it has of resistance to corrosion, only in the case of cast iron it is graphite that is distributed in the form of little flakes. As the iron corrodes, more and more of these graphite flakes are brought to the surface by the very nature of corrosion, and consequently offer a surface which is of greater and greater resistance, and more immune from attack, as the corrosion proceeds.

Uniform distribution of slag has the additional advantage also, that, if this surface barrier is abraded or taken away by any means, it automatically renews itself. I believe the slag content is the reason why wrought iron has more resistance to corrosive attacks, exceeding that of a material which does not have the barrier obstruction.

Mr. Speller. If I might answer a few of the points raised by Mr. Aston, I would emphasize again that the accumulation of service tests, the results of which neither the manufacturers of wrought iron nor any other party have contested, were obtained not on three or four pieces but on hundreds of pieces of presumably the best wrought iron on the market. Good wrought iron has not been clearly defined, but the brand which Mr. Aston so ably advocates was well represented in these tests. Analyses were made, also many microscopic examinations, without any evidence that the amount of cinder or the way it was scattered through the iron had any bearing on the results. If all those who have made such comparative tests have been so unfortunate as to have picked out inferior iron, as Mr. Aston claims, there must be a larger proportion of this on the market of all brands than we would have supposed possible. I do not advocate the use of a mixture of steel scrap in wrought iron, believing that it is better to make pipe of the proper grade of steel throughout; but no evidence has yet been produced, so far as we know, to prove that wrought iron so made is inferior in lasting qualities, and it would be a very easy matter to make such tests. Mr. Aston has spent a lot of time explaining why wrought iron *should* be more lasting than steel on account of the impurities in the form of cinder which it carries. The same argument might obviously be used to prove why it should corrode faster than steel, which is almost free from such foreign matter, for this cinder is, like copper, electro-negative to iron and thus tends to accelerate corrosion locally. Moreover, the cinder is very irregularly distributed and hence does not compare in any way with the graphite in cast iron, to use the comparison made by Mr. Aston. However, theories will not make wrought-iron pipe last longer, and the indisputable facts of experience on the part of hundreds of observers who have had experience with both materials indicates that the assumed difference, which Mr. Aston labors to explain, in fact does not exist.

A few years ago, at one of your meetings (JOURNAL New England Water Works Association, XXVI), Dr. W. H. Walker, director of Research Laboratories, Massachusetts Institute of Technology, referred to "sixty-four comparisons of iron and steel pipe where the history of the installation was known [all taken from service lines in the vicinity of Boston]. The results showed:

Iron more corroded than steel	20
Steel more corroded than iron	18
Iron and steel equally corroded	9
Corrosion negligible	17

"These results again demonstrate that, taken on the average, there is no difference in the corrosion of iron and steel pipe. Conversations held with the engineers in charge of plants during this investigation confirm the statement already made that a pipe is frequently called steel when corrosion is found to be excessive, while it is set down as iron if it rusts but little."

It appears, from this discussion, that, while in New England, as elsewhere, water conditions have much to do with life of service lines, lead, lead-lined, or cement-lined pipe has given satisfactory service so far as internal corrosion is concerned. Steel pipe is free from blisters, and particularly adapted for lining. By providing adequate protection for the outside where necessary, in the form of bituminous soaked fabric or cement casing, according to the character of the soil, it would appear possible to make a wrought service line last as long as desired. The outside and inside protection of iron and steel pipe are two separate problems each requiring special treatment. The Standard Oil Companies have had many steel lines in service twenty years or more in salt marshes and in soil saturated with acid mine water where the pipe is protected by a 2-in. casing of concrete. Such protection might be easily applied where the services pass through foundations, which appears to be a favorite place for corrosion.

MR. ASTON. In answer to Mr. Speller's remarks regarding slag distribution in wrought iron, the more we depart from the exceedingly fine and uniform distribution which was cited in my discussion, the more we digress from the ideal product or from well-made wrought iron; and if any area the size of an average

pit fails to have a multitude of the slag filaments, the product is certainly not a well-puddled wrought iron.

Cinder may tend to promote galvanic action. The potential in conjunction with iron is no doubt, however, rather low. But of greater importance is the quantity of electrical current flow, since the rate of corrosion is proportional to this current. With a certain potential difference, current magnitude depends upon the resistance of the circuit, and since the slag has a very high resistance, the corrosion current is reduced to a relatively small quantity. Furthermore, whatever may be its magnitude, the very corrosion of the iron exposes more and more of the slag barriers; the more rapid the initial corrosion, the sooner the slag becomes the protective surface.

Mr. Speller — and this criticism applies to many citations of tests — compares the qualities of wrought iron and steel on the basis of chemical analyses. I tried to make clear the fact that slag distribution, more than quantity, is the important consideration. Composition depends upon the sampling — quantity and location — and is at best only an average of the quantity of material selected. The more heterogeneous the material, the more the sample is likely to vary from the extremes of composition in the different areas. I have found many examples of so-called wrought iron, poorly made or badly adulterated with steel, which on the face of chemical analyses had all the earmarks of a good product.

Mr. Speller. I would again point out the entire lack of any evidence from service tests as to the protection afforded by cinder in puddled iron. Even if this had been proved, how is any one going to determine whether this cinder is finely distributed, as Mr. Aston says is necessary to accomplish the desired object? If, as he asserts, the hundreds of comparisons of iron and steel pipe from service represent poor wrought iron, the need of some practical means for detecting such iron is very evident.

RAPID SAND FILTRATION.

BY GEORGE A. JOHNSON, CONSULTING HYDRAULIC ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Read September 12, 1917.*]

Foreword.

The subject of this essay, suggested to the author by President Saville, is "Rapid Sand Filtration," an art in the science of water purification first applied in the treatment of municipal water supplies in the year 1885. Up to that time it had been used only in the purification of waters for industrial uses, while slow sand filtration had already gained an accredited standing abroad as a potent aid in the reduction of water-borne diseases. When the rapid sand filter first entered the field of municipal water purification, in 1885, a few small slow sand filter plants had been built in this country, the first of these being at Poughkeepsie and Hudson, N. Y.

The first municipal water filter of the rapid sand type was built at Somerville, N. J., and thus began its wonderful history. From its very inception it established its popularity over all other hitherto attempted methods of purifying water, and has steadfastly held that position throughout the thirty-two years which have since elapsed.

It is not the intention or desire of the author to encroach unduly on the subject of slow sand filtration, which is to be discussed by Mr. Goodnough. He deems it necessary, however, to refer briefly to the use of that process of water filtration in America, and to present certain statistical data for comparison with similar figures for rapid sand filters.

Water Filtration and Disease Prevention.

Twenty-seven years ago, when the art of water filtration was in its infancy in this country, 32 000 residents of continental United States succumbed each year to typhoid fever. This was a death-

rate of about 50 per 100 000 population. To-day, with municipal water filtration plants in operation in 736 communities having a total population of 18 293 000, the number of typhoid fever deaths is about 13 000 annually, corresponding to a death-rate of 13 per 100 000 population living. If the typhoid fever death-rate of twenty-seven years ago existed now, some 750 000 people would suffer from it and 51 000 people would die of the disease in a single year. Since 1890, therefore, because of the public acceptance of lower standards of sanitation than exist to-day, 847 000 people died of typhoid fever in the United States, and easily 10 000 000 suffered from it but recovered.

These figures present a sinister economic aspect. Each death from typhoid fever represents an economic loss to the country of $7 500.* Accordingly, in the past twenty-seven years, due to ignorance and faulty sanitation, the huge sum total of $6 352 500-000 has been dissipated through sickness and death from typhoid fever in the United States. This sum is twice the interest on the total debt so far incurred by all the nations actively involved in the Great War. It is twenty times the property loss in the greatest conflagration of all time, the San Francisco fire of 1906. It would build 200 000 miles of the best bituminous-macadam roads, and is equal to two thirds of all the money on deposit in United States national and savings banks.

The present generation has seen great advances in numerous branches of municipal sanitation other than the purification of public water supplies. Unquestionably some of these have been potent factors in the diminution of typhoid fever in America, and while it is not the author's intent to attribute to purer water the entire credit for this improvement, he believes the facts prove that the substitution of pure for polluted water supplies was by long odds the most important cause contributing to this end. A fair argument for this viewpoint is found in Table 1.

The figures shown in Table 1 are very suggestive. When the ratio of population supplied with filtered water to total urban population in the United States increased from 1 in 80 to 1 in 18 in the decade 1890–1900, the urban typhoid fever death-rate

* "The Typhoid Toll." *Journal American Water Works Association*, Vol. 3, No. 2, p. 254, June, 1916.

TABLE 1.

TYPHOID FEVER DEATH-RATES AND POPULATIONS SUPPLIED WITH FILTERED WATER.

Year.	Estimated Urban Population of the United States.	Total Population Supplied with Filtered Water.	Proportion of Filtered Water Population to Total Urban Population.	Typhoid Fever Death-Rate per 100 000 Population in Urban United States.
1890	25 000 000	310 000	1 in 80	48
1900	34 000 000	1 860 000	1 in 18	40
1910	44 000 000	10 805 000	1 in 4	27
1917	51 000 000	18 293 000	1 in 3	13

decreased 17 per cent. When this ratio again increased from 1 in 18 to 1 in 4 in the decade 1900–1910, the typhoid fever death-rate showed a decrease of 32 per cent. in the same period; and when the ratio of " filtered water population " to total urban population again increased from 1 in 4 to 1 in 3 in the six-year period ending in 1917, the urban typhoid fever death-rate fell 52 per cent. The relationship between the increasing number of people receiving filtered water and the decrease in the typhoid fever death-rate is too positive to permit the dismissal of the phenomenon on the grounds of mere coincidence.

There is another feature in connection with disease reduction by water filtration to which attention must be called, and that is, that where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided. This is known as Hazen's theorem. The records from fifteen representative cities * bear out this assumption in a striking manner, as follows:

TABLE 2.

DEATH-RATES FROM ALL CAUSES AND FROM TYPHOID FEVER IN CITIES BEFORE AND AFTER FILTRATION.

Per 100 000 Population.	Before Filtration.	After Filtration.
Total death-rate	1 870	1 730
Typhoid fever death-rate	67	25
Typhoid lives saved	—	42
Other lives saved	—	98

* " Present-Day Water Filtration Practice." *Journal American Water Works Association*, Vol. 1, No. 3, p. 516, 1914.

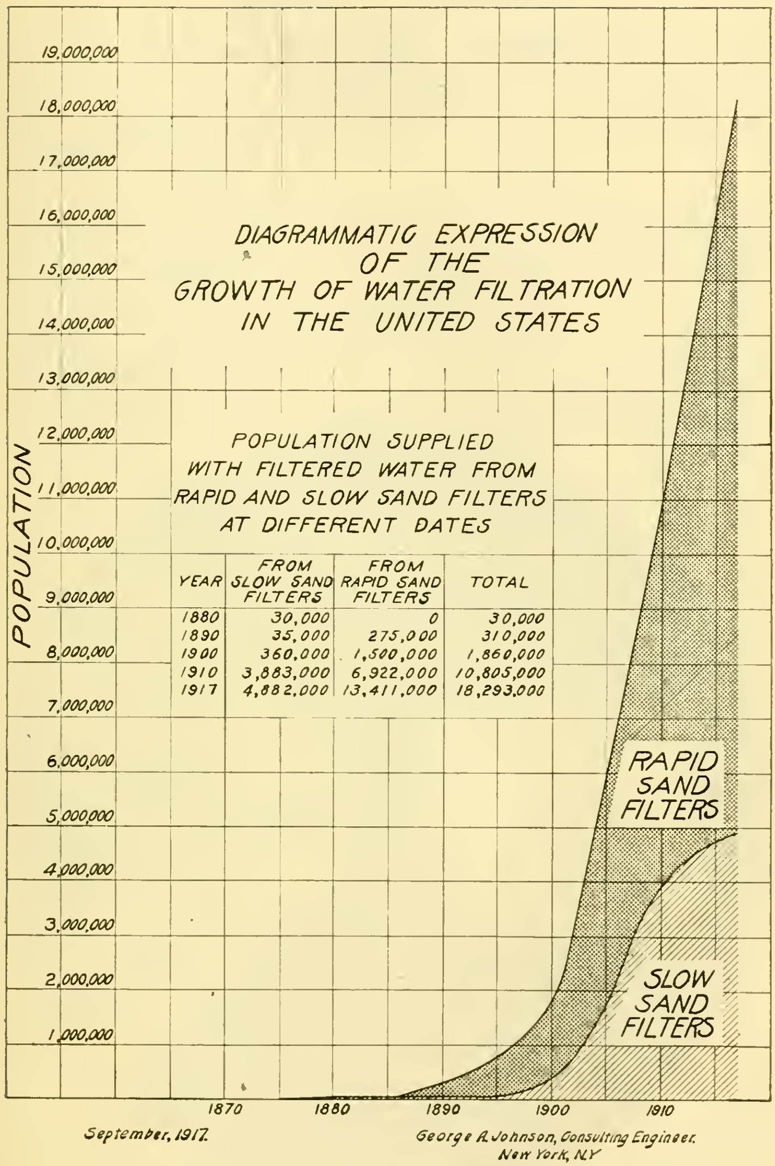
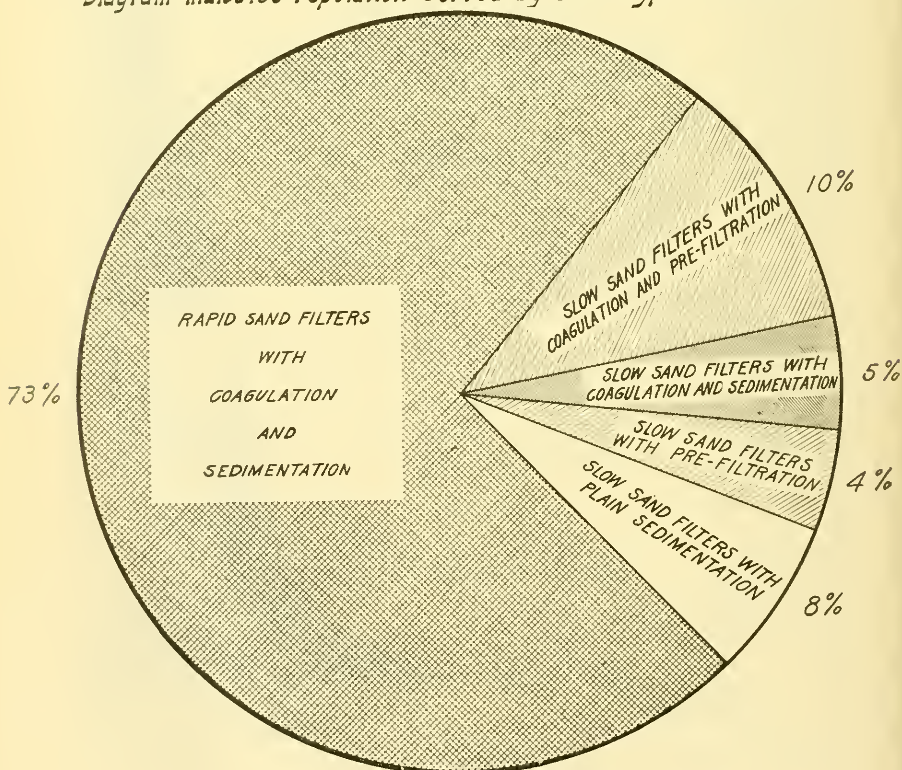

DIAGRAMMATIC EXPRESSION
OF THE
GROWTH OF WATER FILTRATION
IN THE UNITED STATES
POPULATION SUPPLIED
WITH FILTERED WATER FROM
RAPID AND SLOW SAND FILTERS
AT DIFFERENT DATES
YEAR | FROM SLOW SAND FILTERS | FROM RAPID SAND FILTERS | TOTAL
1880 | 30,000 | 0 | 30,000
1890 | 35,000 | 275,000 | 310,000
1900 | 360,000 | 1,500,000 | 1,860,000
1910 | 3,883,000 | 6,922,000 | 10,805,000
1917 | 4,882,000 | 13,411,000 | 18,293,000
POPULATION
19,000,000
18,000,000
17,000,000
16,000,000
15,000,000
14,000,000
13,000,000
12,000,000
11,000,000
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
1870
1880
1890
1900
1910
RAPID SAND FILTERS
SLOW SAND FILTERS
September, 1917.
George A. Johnson, Consulting Engineer.
New York, N.Y.

FIG. 1.

DIAGRAMMATIC EXPRESSION
OF
MUNICIPAL WATER FILTRATION
IN THE
UNITED STATES

SYSTEM	DAILY FILTERING CAPACITY (GALLONS)	POPULATION SERVED
RAPID SAND FILTERS	2388,000,000	13,411,000
SLOW SAND FILTERS WITH PLAIN SEDIMENTATION	196,000,000	1,221,000
" " " " PRE-FILTRATION	218,000,000	807,000
" " " " COAGULATION & SEDIMENTATION	115,000,000	874,000
" " " " COAGULATION & PRE-FILTRATION	393,000,000	1,980,000
ALL KINDS	3,310,000,000	18,293,000

Diagram Indicates Population Served by Each Type of Filter



September, 1917.

George A. Johnson, Consulting Engineer.
New York, N.Y.

FIG. 2.

These data show with much positiveness the soundness of the so-called Hazen's theorem, and prove in a striking manner that where one typhoid death was avoided by the substitution of pure for impure water, at least two other deaths from causes less well defined were also prevented.

Growth of Water Filtration in North America.

The accompanying diagram, Fig. 1, shows the growth of filtration of municipal water supplies in the United States since the first filter was built at Poughkeepsie in 1874, some forty-three years ago. One of the most striking features of this diagram is the positiveness with which rapid sand filtration has outgrown the older slow sand method. Of the 18 293 000 people now supplied with filtered water in the United States, 73 per cent., or 13 411 000, are supplied from 682 rapid sand filter plants, the remaining 27 per cent., or 4 882 000 people, being served from 54 slow sand filter plants. (See Fig. 2.)

Once the rapid sand process appeared in the field it assumed the lead, and has steadily forged still further ahead. The same thing is also true in Canada. In the Dominion, there are now some 45 municipal filter plants supplying a total of about 1 500 000 people, or about one in every six of the total population. Thirty-nine of these plants are rapid sand filters serving about 1 000 000 people. In foreign countries, there are some 81 municipal rapid sand filter plants with a total daily filtering capacity of about 175 000 000 U. S. gal., and serving about 3 500 000 people.

Detailed tabulations of rapid and slow sand filter installations in North America, and of rapid sand filter plants in foreign countries, are to be found in Tables 7 to 11.

Summarizing, the following shows the existing status of water filtration so far as the available data will allow:

TABLE 3.

STATUS OF MUNICIPAL WATER FILTRATION IN NORTH AMERICA.

January, 1917.		United States.	Canada.	Totals.
Number of places.	Rapid sand........	682	39	721
	Slow sand.........	54	6	60
	Total.............	736	45	781
Total population served.	Rapid sand........	13 411 000	1 000 000	14 411 000
	Slow sand.........	4 882 000	500 000	5 382 000
	Total.............	18 293 000	1 500 000	19 793 000
Proportion of "filtered water population" to total population.	Rapid sand.......	1 : 7.6	1 : 9	1 : 7.7
	Slow sand........	1 : 20.9	1 : 18	1 : 20.6
	Total............	1 : 5.6	1 : 6	1 : 5.6

Since 1910, the progress in municipal water filtration in the United States has been noteworthy. The population supplied with filtered water has increased 69 per cent., and the total capacity of the filter plants in operation has increased 81 per cent. The increase in rapid sand filtration has been particularly marked in the last six years, the population served by filters of this type having increased by 94 per cent., as compared with an increase of 26 per cent. for slow sand filters. The daily filtering capacity of slow sand filter plants has increased by 11 per cent. since 1910, whereas the capacity of rapid sand filter plants has shown an increase of 139 per cent. This is explainable by the fact that the increase in the population served by slow sand filters is accounted for chiefly by the natural increase in population in cities which already had filter plants in 1910, but few new slow sand filter plants having been built since that time. The increase in population served by rapid sand filters since 1910, however, was principally due to the construction of new filter plants, as, for example, those built at Akron, Ohio; Baltimore, Md.; Dallas, Tex.; Erie, Pa.; Grand Rapids, Mich.; Minneapolis, Minn.; St. Louis, Mo.; and Trenton, N. J. These eight plants alone provided a filtering capacity of 462 000 000 gal. daily, and serve a total present population of 2 400 000.

Since 1910, the most notable additions to the slow sand filters in operation are the plants at Brookline and Lowell, Mass., and the Queen Lane plant at Philadelphia. The two Massachusetts

plants were built especially with iron and manganese removal in view. One large slow sand plant, that at Wilmington, Del., is now being supplemented by a rapid sand plant of modern design.

TABLE 4.

Increase in Municipal Water Filtration in the United States since the Year 1910.

(January, 1917.)

	Year.	Rapid Sand Filters.	Slow Sand Filters.	Total.
Population served	1910	6 922 000	3 883 000	10 805 000
	1917	13 411 000	4 882 000	18 293 000
Per cent. increase.....	....	94	26	69
Daily filtering capacity (gallons)	1910	1 000 000 000	830 000 000	1 830 000 000
	1917	2 388 400 000	921 900 000	3 310 300 000
Per cent. increase.....	....	139	11	81

Modified Use of Slow Sand Filters.

A noteworthy feature in connection with slow sand filtration practice in America is that alterations have been made in the layouts originally designed for several large cities, with the adoption of either pre-filtration, or coagulation, or both, in the pre-treatment of the water before final filtration through the slow sand filters. Thus at Albany, coagulating basins and preliminary roughing filters have been added to the original slow sand filter plant to lessen the load on the final filters and permit them to do satisfactory work. For the same reason, preliminary filters were added to the Pittsburgh plant two years after the original plant went into operation. Philadelphia has adopted coagulation of the raw water at four out of five plants, and at Washington and Poughkeepsie, coagulation of the raw water now forms a part of the preparatory treatment.

Of the forty cities wherein the slow sand filters are operated as such without radical modifications, those of Denver, New Haven, Yonkers, Reading, Providence, and Philadelphia (Upper Roxborough) are the largest, and have a combined daily capacity of 124 000 000 gal. The remaining thirty-five plants are small, averaging a daily capacity of 2 000 000 gal.

Of the fifty-four cities having slow sand filter plants now in service in the United States, with a total daily filtering capacity of 922 000 000 gal., forty provide no pre-treatment other than plain sedimentation in impounding reservoirs or settling basins. The plants in these forty cities have a total rated daily capacity of 196 000 000 gal., or an average of 4 900 000 gal. daily.

The remaining fourteen cities have slow sand plants with a total filtering capacity rated at 726 000 000 gal. In five of these cities, slow sand filtration is preceded by pre-filtration at high rate; in four cities, by coagulation and pre-filtration; in one city (Philadelphia), by coagulation and pre-filtration at four plants; and in the remaining five cities by coagulation and sedimentation.

TABLE 5.

PREPARATORY TREATMENT OF WATER PRIOR TO SLOW SAND FILTRATION.

Number of Cities.	Kind of Preparatory Treatment.	Total Daily Filtering Capacity. Gallons.	Per Cent. of Total.
40*	None, other than plain sedimentation in impounding reservoirs or settling basins.	196 000 000	21.3
4*	Coagulation and pre-filtration.	393 000 000	42.7
5	Coagulation and sedimentation.	115 000 000	12.4
6	Pre-filtration only.	218 000 000	23.6

STATISTICS OF GEOGRAPHICAL GROUPING OF MUNICIPAL FILTERS.

One third of the total population of the United States supplied with filtered water is located in the Middle Atlantic District, comprising the states of New York, New Jersey, and Pennsylvania. The urban population in this district is proportionately large,† however, when compared with similar figures for other districts. This fact, and the big slow sand filter plants at Albany, N. Y.,

* Philadelphia counted twice, since coagulants are not used at all five plants.

† Ratio of urban population to total population in the state:

	Per Cent.
New York	74.3
New Jersey	64.5
Pennsylvania	47.7
The three states	62.4

Philadelphia, Pittsburgh, and Reading, Pa., and the large rapid sand filter plants at Binghamton and Niagara Falls, N. Y., Little Falls, New Milford, and Trenton, N. J., Erie, Harrisburg, and South Pittsburgh, Pa., in a material fashion served to increase far above the average the ratio of population provided with filtered water to total population. Elsewhere in the country it is quite noteworthy how remarkably proportionate is the subdivision of the population receiving filtered water with the subdivision of the population of the country by districts.

TABLE 6.

Slow Sand Filter Plants in the United States.

(January, 1917.)

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Arizona	1	4 000	300 000
Colorado	4	150 000	42 500 000
Connecticut	4	141 000	25 000 000
Delaware	1	102 000	12 000 000
District of Columbia	1	389 000	75 000 000
Indiana	1	333 000	20 000 000
Maine	1	15 000	4 000 000
Massachusetts	8	396 000	40 300 000
New Hampshire	3	30 000	4 000 000
New Jersey	1	2 000	200 000
New York	13	348 000	57 200 000
North Carolina	1	2 000	300 000
Pennsylvania	8	2 620 000	607 000 000
Rhode Island	1	263 000	18 000 000
South Dakota	1	3 000	400 000
Texas	1	12 000	1 000 000
Vermont	1	9 000	2 500 000
Wisconsin	3	63 000	12 200 000

In Tables 7 to 11 inclusive, statistics covering the number of rapid and slow sand filter plants, population served, and capacity of works, are given by states and geographical groupings.

In the New England District, 24 per cent. of the total urban population are supplied with filtered water, and in the past ten years the filter capacity has increased by 58 per cent.

In view of the relatively greater congestion of the population in New York, New Jersey, and Pennsylvania, it is by no means remarkable that the Middle Atlantic District stands at the head of all the districts in the use of filtered water. The pollution of the rivers and lakes from which the bulk of the community centers of this district draw their water supplies is steadily increasing, and filtration is recognized as an absolutely necessary measure of protection. In fact, there are but seven cities in the district having populations in excess of 100 000 where filtration of the water supply is not practiced, namely, New York, Buffalo, Camden, Jersey City, Newark, Rochester, and Syracuse. In a number of these cities, filtration is being agitated, and for years has been considered advisable. Doubtless at the close of the present decade, at least two and probably more of these cities will have adopted filtration. It is noteworthy that in this district, on the basis of population served, municipal water filtration has increased by practically 100 per cent. in the past six years.

In the South Atlantic, East North Central, and West North Central districts, 40.5, 32.0, and 35.9 per cent. respectively of the urban population are now supplied with filtered water. Particularly marked increases during the past ten years in Maryland, Ohio, Illinois, Minnesota, Michigan, Missouri, and Kansas are largely responsible for the present showing.

In the East South Central District, 20.2 per cent. of the urban population is supplied with filtered water, the relatively small increase in filter capacity in this district in recent years having been largely due to some additions in Kentucky. The lack of activity along water filtration lines in this district is worthy of mention and hard to explain, for the typhoid record of the district is far from good. Kentucky, for example, the only state in the district from which entirely reliable mortality statistics are available, has an annual typhoid fever death-rate nearly three times the average for all the registration states, with a population of over 60 000 000.

In the West South Central District, 25.2 per cent. of the urban population is supplied with filtered water. Advances in Texas played the most important part in the increased filter capacity in this district during the last decade.

In the Mountain and Pacific districts, 23.7 and 18.0 per cent. respectively of the urban population are supplied with filtered water. Large numbers of the public supplies continue to be taken from mountain streams and lakes.

TABLE 7.

List of Slow Sand Filter Plants in Operation in the United States.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Arizona.			
Yuma	2 910	1903	0.3
Colorado.			
Buena Vista	1 040	——	0.5
Canon City	5 160	1908	2.0
Denver	113 400	1890	35.0
Greeley	8 180	1906	5.0
Connecticut.			
Bethel	3 790	——	0.5
New Haven	100 000	1905	20.0
Putnam	7 280	——	2.0
South Norwalk	8 970	1907	2.5
Delaware.			
Wilmington	87 400	1909	12.0
District of Columbia.			
Washington	331 100	1905	75.0
Indiana.			
Indianapolis	282 900	1903	20.0
Maine.			
Augusta	13 210	1914	4.0
Massachusetts.			
Brookline	27 800	1915	5.0
Greenfield	10 430	——	1.0
Lawrence	85 890	1893–1907	6.0
Lowell	106 290	1915	10.0
Marblehead	7 340	1908	2.0
Marion	1 000	——	0.3
Middleboro	8 210	1913	1.0
Springfield	88 930	1906	15.0

TABLE 7. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
	New Hampshire.		
Dover	13 250	1902	2.0
Franklin	6 130	——	0.5
Somersworth	6 700	1897	1.5
	New Jersey.		
Matawan	1 650	——	0.2
	New York.		
Albany	100 250	1899	25.0
Brooklyn	10 000	1909	1.0
Deposit	1 860	——	0.5
Geneva	12 450	1911	3.0
Hudson	11 420	1876	2.5
Ilion	6 590	——	1.2
Mechanicville	6 630	——	2.0
Nyack	4 620	1899	2.0
Ogdensburg	15 930	1912	3.0
Peekskill	15 240	1909	3.0
Poughkeepsie	27 940	1874	3.0
Westfield	2 990	——	1.0
Yonkers	79 800	1906	10.0
	North Carolina.		
Marion	1 520	——	0.3
	Pennsylvania.		
Apollo	3 010	——	2.0
Berwin	1 000	1898	2.0
Coatesville	11 080	1915	2.0
Philadelphia	1 549 000	1902	368.0
Pittsburgh	533 900	1908	200.0
Reading	96 070	1903–1915	25.0
South Bethlehem	19 970	1904	4.0
Steelton	14 250	1907	4.0
	Rhode Island.		
Providence	224 330	1904	18.0
	South Dakota.		
Hot Springs	2 140	——	0.4

TABLE 7. — *Concluded.*

TEXAS.

City.	1910 Population.	Date Installed.	Capacity (M.G.D.)
San Angelo	10 320	——	1.0
VERMONT.			
St. Johnsbury	8 100	1897	2.5
WISCONSIN.			
Ashland	11 590	1895	2.0
Mellen	1 830	——	0.2
Superior	40 380	1899	10.0

TABLE 8.

RAPID SAND FILTER PLANTS IN THE UNITED STATES.

(January, 1917.)

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Alabama	13	255 000	33 400 000
Arkansas	9	107 000	16 100 000
California	16	370 000	36 300 000
Colorado	4	129 000	24 900 000
Connecticut	5	29 000	6 200 000
Delaware	1	102 000	12 000 000
Georgia	29	511 000	66 500 000
Iowa	21	304 000	41 700 000
Indiana	18	343 000	63 000 000
Illinois	36	507 000	111 100 000
Kansas	32	298 000	43 600 000
Kentucky	19	480 000	114 000 000
Louisiana	4	473 000	52 500 000
Maine	8	75 000	20 300 000
Maryland	10	723 000	145 900 000
Massachusetts	4	22 000	4 700 000
Michigan	10	263 000	53 400 000
Minnesota	11	465 000	67 100 000
Missouri	31	1 165 000	208 400 000
Mississippi	5	67 000	13 300 000

TABLE 8. — *Continued.*

State.	Number of Places.	Total Population Served. (Estimated.)	Total Daily Filtering Capacity. (Gallons.)
Montana	6	38 000	22 800 000
Nebraska	1	6 000	400 000
New Hampshire	3	26 000	2 700 000
New Jersey	31	1 286 000	179 200 000
New Mexico	1	5 000	1 500 000
New York	50	558 000	142 100 000
North Carolina	38	347 000	45 600 000
North Dakota	6	46 000	8 800 000
Ohio	46	1 560 000	324 900 000
Oklahoma	25	228 000	40 400 000
Oregon	10	36 000	12 400 000
Pennsylvania	90	1 266 000	283 200 000
Rhode Island	5	73 000	13 500 000
South Carolina	15	186 000	23 800 000
South Dakota	1	6 000	1 500 000
Tennessee	8	128 000	24 500 000
Texas	18	395 000	41 300 000
Vermont	2	27 000	2 600 000
Virginia	14	227 000	28 600 000
Washington	2	9 000	1 500 000
West Virginia	13	127 000	22 100 000
Wisconsin	7	128 000	24 500 000
Wyoming	4	15 000	6 100 000

TABLE 9.

LIST OF RAPID SAND FILTER PLANTS IN OPERATION IN AMERICA.

(January, 1917.)

[NOTE. — (P) represents pressure filters.]

ALABAMA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Birmingham	166 150	1906	20.0
Bessemer	———	1916	0.1
Cordova	1 750	———	0.3
Decatur	4 230	1910	2.5
Eufaula (P)	4 260	1907	0.5
Flat Top	500	1916	0.1
Florence	6 690	1916	1.5

TABLE 9. — *Continued.*

ALABAMA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Gadsden	10 560	1910	2.0
Montgomery	——	——	1.0
New Decatur	6 100	1911	2.5
Opelika	4 730	——	0.7
Pratts	2 000	1913	0.2
Tuscaloosa	9 820	1914	2.0
ARKANSAS.			
Arkadelphia (P)	2 750	1915	0.6
Conway (P)	2 790	1910	0.5
Eureka Springs	3 230	1914	0.8
Fort Smith	23 970	1913	3.0
Little Rock (P)	45 940	1891–1897	8.5
Luxora	1 000	1914	0.3
Morrilltown (P)	2 420	1912	0.4
Newport (P)	3 560	1910	0.5
Texarkana	5 660	——	1.5
CALIFORNIA.			
Antioch (P)	1 120	1915	0.7
Black Diamond (P)	2 370	1909	0.7
Cherry Canon (P)	1 000	1912	0.2
Eureka (P)	13 770	1912	1.5
Fort Baker (P)	500	1912	0.1
Merced Falls (P)	500	1912	0.1
Oakland (P)	219 650	1891	7.0
Portersville (P)	2 700	1891	0.2
Presidio (P)	1 000	1911	1.0
Rio Vista	500	——	0.4
Riverside (P)	18 300	1892	0.1
San Diego (P)	48 620	1906–1915	10.0
San Francisco (P)	——	1912	12.5
Scotia	700	1913	0.1
Spring Valley (P)	——	1912	1.0
Watsonville	4 450	1908	0.7
COLORADO.			
Berthoud	1 000	1907	0.7
Denver	100 000	1890	20.0
Fort Collins	8 200	1910	4.0
Sugar City	1 100	1907	0.2

TABLE 9. — *Continued.*

CONNECTICUT.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Bethel	1 900	——	0.5
Collinsville (P)	3 000	1916	0.2
Greenwich (P.)	16 460	1887–1909	3.5
New Canaan (P)	3 670	1913	1.0
Norwich (P)	——	1911	1.0

DELAWARE.

Wilmington	87 400	1916	12.0

GEORGIA.

Athens	14 900	1909–1912	5.0
Atlanta (P)	224 460	1887–1910	21.0
Augusta	47 740	1889–1912	9.0
Carrollton	3 300	1905	0.5
Cartersville	4 070	1912	1.0
Columbus	20 550	1903–1912	6.0
Commerce	2 240	——	0.3
Covington	2 700	——	0.7
Cuthbert	3 210	1910	0.5
Dalton	5 320	1908	0.5
Decatur	2 470	1912	1.0
Eatonton	2 040	1897	0.3
Elberton	6 480	1904	0.5
Gainesville	5 920	1911	1.0
Jackson	1 860	——	0.4
Jefferson	1 210	1915	0.3
La Grange	5 590	——	1.5
Macon	40 660	1898–1916	8.0
Madison	2 410	1907	0.4
Marietta	5 950	1908	1.0
Milledgeville	4 380	1910	1.0
Milledgeville (Hospital)	——	1893	0.5
Monroe	3 030	1905	0.5
Perry	1 000	——	0.7
Rome	14 400	1908–1912	3.0
Tallapoosa	2 120	——	0.3
Thomaston	1 640	1912	0.5
Toccoa	3 120	——	0.1
West Point	1 910	1902	1.0

TABLE 9. — *Continued.*

ILLINOIS.

City	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Alton	17 530	1906–1915	4.0
Cairo	14 550	1910	4.0
Carlinville	3 620	1907	1.0
Champaign	12 420	1912	2.0
Charleston	5 880	1912	1.0
Chicago Stock Yards	———	1908	5.0
Danville	27 870	1903–1910	3.7
Decatur	31 140	1914	9.0
East St. Louis (P)	58 550	1900	17.0
Elgin (P)	25 980	1898	3.5
Evanston	24 980	1914	12.0
Freeport	17 570	1903–1913	4.0
Fort Sheridan (P)	1 800	1912	2.0
Hamilton	1 630	1912	1.0
Harrisburg	5 300	1914	0.9
Herrin	6 860	1915	1.0
Hinsdale	2 450	1914	1.0
Kankakee	17 170	1905–1907	4.0
Kenilworth (P)	500	1907–1909	1.6
Lake Forest (P)	3 350	1892	1.0
Lawrenceville	3 230	1913	0.7
McLeansboro (P)	1 800	1912	0.2
Macomb	5 780	1913	1.0
Moline	24 200	1903–1913	5.7
Mt. Carmel	6 930	1910	1.0
Mt. Vernon	8 010	1913	1.5
Murphysboro	7 480	1915	2.2
Pana	6 060	1911	1.0
Pontiac	6 090	1898	1.5
Quincy	36 590	1914	6.0
Rock Island	24 300	1910	6.0
Rock Island (Arsenal)	2 000	1912	1.5
Rogers Park (P)	1 000	1889–1906	0.9
Sparta	3 080	1915	0.5
Streator	14 250	1889	2.5
Warsaw	2 250	1912	0.2

TABLE 9. — *Continued.*

INDIANA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Anderson	22 480	1904–1916	5.0
Aurora	4 410	1904	1.0
Columbus	8 810	1912	4.0
Evansville	71 280	1910	12.0
Jasper (P)	2 200	1916	1.0
Logansport	19 050	1913	8.0
Mount Vernon	5 560	1913	2.0
Muncie (P)	24 000	——	4.0
New Albany	20 630	1916	4.0
Paoli (P)	1 280	1916	0.5
Princeton	6 450	1915	3.0
Seymour	6 300	1905	2.0
Terre Haute (P)	64 600	1890–1900	9.0
Valparaiso	6 990	1907	2.0
Vincennes	14 900	1890	2.0
Warsaw	4 430	1896	0.5
Washington	7 850	1906	2.0
West Baden (P)	1 000	1907	1.0

IOWA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Ames	4 220	1915	0.9
Burlington	24 320	1905	5.0
Cedar Rapids	32 810	1912	4.0
Centerville (P)	6 940	1913–1916	0.7
Chariton (P)	3 790	1916	0.5
Clear Lake (P)	2 010	——	0.4
Clinton (P)	25 580	1899	1.0
Creston	6 920	1893	1.0
Davenport (P)	43 030	1891–1908	9.0
Fairfield	4 970	1911	1.0
Fort Madison	8 900	1916	3.0
Indianola	3 280	1905	0.5
Iowa City	10 090	1909	2.0
Keokuk (P)	14 010	1893	3.5
Lenox (P)	1 270	1914	0.2
Oskaloosa (P)	9 470	1902	1.3
Mount Pleasant	3 870	1888	0.5
Osceola	2 720	1912	0.2
Ottumwa	22 010	1911	4.0
Storm Lake	2 430	1912	0.5
Waterloo	26 690	1907	2.5

TABLE 9. — *Continued.*

KANSAS.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Augusta	1 300	1911	0.5
Baldwin	1 390	1909	0.1
Burlingame	1 550	1913	0.3
Burlington	2 180	1914	0 8
Caldwell (P)	2 250	1890	0.5
Chanute	9 270	1914	1.0
Cherryvale	4 940	1911	1.4
Coffeyville	18 500	1913	4.0
Council Grove (P)	2 670	1914	1.0
Douglas	1 000	1914	0.3
Emporia	9 060	1915	3.0
Fredonia	3 040	1915	1.0
Garnett	2 330	1907	0.5
Horton	3 600	1912	1.0
Humboldt	2 550	1916	0.3
Independence	10 480	1914	4.5
Jewell City	1 000	1913	0.2
Kansas City	131 980	1910	11.5
Lansing	1 000	——	0.2
Lyndon	800	1913	0.3
Marysville	2 260	1914	0.5
Mound City	1 000	1911	0.3
Olathe	3 270	1914	0.5
Osage City	2 430	——	0.5
Osawatomie	4 050	1915	1.0
Oswego	2 790	1916	1.0
Paola (P)	3 210	1887	0.2
Parsons	12 460	——	3.0
Pleasanton	1 370	1915	0.2
Russell	1 690	1911	0.5
Washington	1 550	1914	0.5
Winfield	6 700	1894–1908	3.0

KENTUCKY.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Ashland	8 690	——	3.0
Bardstown	2 130	1915	0.5
Bowling Green (P)	9 170	1910	3.0
Campbellsville	1 210	1914	0.5
Catlettsburg	3 520	——	4.0
Danville	5 700	1905	2.5
Frankfort	10 460	1912	6.0

TABLE 9. — *Continued.*

KENTUCKY. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Georgetown	4 530	1910	0.7
Henderson	11 450	1916	3.5
Hopkinsville	9 420	1897	0.5
Lancaster	1 510	1912	0.5
Lexington	35 100	1895	4.0
Louisville	263 260	1905–1914	72.0
Mt. Sterling	3 830	1912	1.0
Paducah	22 760	1904	7.0
Paris	5 860	1905	1.0
Shelbyville	4 700	1915	1.0
Somerset	6 880	1912	1.0
Winchester	7 160	1904	2.3
LOUISIANA.			
Morgan City	5 480	1912	1.0
New Iberia	7 500	1915	0.5
New Orleans	361 220	1909	44.0
Shreveport	28 020	1899–1916	7.0
MAINE.			
Bangor	24 800	1912	8.0
Belfast	4 620	1914	1.1
Biddeford	17 080	1910	5.5
Kennebunk (P)	3 100	1915	2.0
Mechanic Falls	1 680	——	0.7
Oldtown (P)	6 320	1901	1.5
Rumford Falls	5 430	——	0.5
Veazie	1 000	——	1.0
MARYLAND.			
Avalon	1 500	1910–1914	2.5
Baltimore	558 480	1914	128.0
Catonsville (P)	4 500	1890	0.3
Cumberland	21 840	1913	8.0
Elkton	2 490	1912	1.0
Hagerstown	16 510	1912	4.0
Havre de Grace	4 210	1906	1.0
Laurel	2 420	1915	0.5
Sparrows Point	4 000	1895	0.3
Tacoma Park	500	1910	0.3

TABLE 9. — *Continued.*

MASSACHUSETTS.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Athol	8 530	1888	1.5
Cohasset	2 590	1914	1.0
Pepperell	3 000	——	0.7
Reading	5 820	1910	1.5
MICHIGAN.			
Adrian	10 760	1914	3.0
Ann Arbor	14 820	——	3.0
Dearborn	1 500	1914	2.0
Escanaba	13 190	1908	6.0
Flint	38 550	1912	9.0
Grand Rapids	112 570	1911	25.0
Iron River (P)	2 450	1907	0.2
Ironwood	12 820	1910	1.2
Menominee	10 510	1916	3.0
Mt. Clemens (P)	7 710	1888	1.0
MINNESOTA.			
Brainerd (P)	8 530	1897	0.5
Breckenridge	1 840	1910	1.0
Carlton	800	1916	0.2
Chisholm	7 680	1906–1914	2.0
Crookston	7 560	1911	0.5
East Grand Forks	2 530	1909	1.0
Ely	4 050	1904	1.0
Gilbert	1 700	1915	0.5
Kinney (P)	1 000	1916	0.3
McKinley (P)	500	1902	0.1
Minneapolis	360 360	1911	60.0
MISSOURI.			
Bertany	1 930	1912	0.3
Boonville	4 250	1905	1.0
Butler	2 890	1916	0.5
Canton (P)	2 220	1911	0.2
Carthage	9 480	1905	2.0
Chillicothe	6 270	1915	1.2
Excelsior Springs	3 900	1914	1.0
Hermann	1 590	1912	0.7
Holden (P)	2 010	1893	0.3

TABLE 9. — *Continued.*

MISSOURI. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Independence........	10 070	1905	1.0
Joplin...............	32 070	——	7.0
La Grange (P).......	3 260	1914	0.3
Lamar...............	2 320	1891	0.3
Liberty..............	2 980	1912	0.5
Louisiana (P)........	4 450	1888–1889	1.8
Macon..............	3 580	1914	0.7
Maryville (P)........	4 760	1913	0.8
Mexico (P)..........	5 940	1889	0.8
Monroe City.........	1 950	1913	0.4
North Kansas City...	1 000	1913	0.5
Palmyra.............	2 170	1914	0.4
Paris................	1 470	1916	0.5
Rich Hill (P).........	2 760	1886	0.3
Sedalia	17 820	1915	3.0
St. Joseph (P)........	77 400	1898	14.0
St. Louis............	734 670	1914	160.0
Shelbina.............	2 170	1911	0.4
Slater...............	3 240	1916	0.6
Springfield...........	35 200	1910	6.0
Trenton (P)..........	5 660	1916	1.2
Washington (P)......	3 670	1888–1904	0.7
	MISSISSIPPI.		
Columbus............	8 990	1899–1907	2.0
Jackson.............	1 910	1915	5.0
Macon..............	2 020	1906	0.3
Meridian............	23 290	——	3.0
Vicksburg...........	20 810	1904	3.0
	MONTANA.		
Billings..............	10 030	1915	6.0
Chinook.............	1 000	1915	0.5
Great Falls..........	13 950	1916	12.0
Harlem..............	800	1911	0.3
Miles City...........	4 700	1910	2.0
Glendive.............	2 430	1916	2.0
	NEBRASKA.		
Nebraska City (P)....	5 490	1891	0.4

TABLE 9. — *Continued.*

New Hampshire.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Berlin	11 780	——	1.5
Exeter (P)	4 900	1887	0.2
Lebanon	5 720	1907	1.0

New Jersey.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Allenhurst (P)	500	1910	0.5
Allentown	800	1910	0.1
Asbury Park (P)	10 150	1895	2.0
Atlantic Highlands (P)	1 650	1894–1910	1.0
Bordentown (P)	4 250	1890	0.5
Bound Brook (P)	3 970	1913	2.0
Bridgeton	14 210	1913	3.0
Burlington	8 340	1910	3.0
Elizabeth (P)	——	——	1.5
Flemington	2 690	1914	0.3
Franklin	2 400	1914	0.1
Gloucester	9 460	1904	2.0
Heightstown	1 880	1899	0.3
Keyport	3 550	1895	0.5
Keansburg Beach (P)	1 000	1912	0.2
Kirkwood	1 000	——	0.2
Lakewood (P)	5 150	1899	0.5
Little Falls	425 000	1902	43.0
Long Branch (P)	13 300	1888–1894	3.0
Merchantville (P)	2 000	1911	1.0
Moorestown	4 000	1905	1.0
Mt. Holly	5 750	1902	2.0
New Milford	425 000	1906	48.0
New Brunswick	23 390	1916	6.0
Penn Grove (P)	2 120	1910	0.5
Rahway (P)	9 340	1907–1910	10.6
Raritan (P)	8 730	1885–1913	3.0
Red Bank	7 400	1900	12.0
Roebling	1 500	——	1.0
South Plainfield	500	1906	0.4
Trenton	96 820	1914	30.0

New Mexico.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Raton	4 540	1914	1.5

TABLE 9. — *Continued.*

NEW YORK.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Albion	5 020	1914	1.0
Attica (P)	1 870	1896	0.4
Bainbridge (P)	1 160	1911	0.3
Batavia	11 610	1916	3.0
Binghamton	48 440	1902–1913	17.0
Brockport	3 580	1905–1913	2.5
Brooklyn	65 000	1903	8.0
Charlotte (P)	1 940	1907	0.5
Cobbleskill (P)	2 090	1914	0.6
Cohoes	24 710	1910	8.0
East Worcester (P)	1 000	1911	0.3
Elmira	37 180	1897	7.0
Fort Porter (P)	1 000	1914	0.3
Green Island	4 740	1902	1.0
Hilton	1 000	1915	0.3
Hornell (P)	13 620	1899–1904	3.0
Ithaca	14 800	1903	3.5
Kingston (P)	25 910	1892–1902	6.0
Kirkwood (P)	1 000	1912	0.3
Lewiston	1 000	1916	0.3
Le Roy	3 770	1915	0.5
Lyons	4 460	1915	1.0
Madrid	1 000	1915	0.3
Middletown (P)	15 310	1900–1909	5.0
Mt. Morris (P)	2 780	1914	0.5
Niagara Falls	30 450	1910–1912	26.0
North Tarrytown	5 420	——	3.0
Norwich (P)	7 420	1904–1907	3.0
Oneonta (P)	9 490	1906	3.0
Owego (P)	4 630	1887–1893	0.8
Pleasantville (P)	2 210	1908	0.1
Rensselaer	10 710	1901	4.0
Richfield Springs (P)	1 500	1889	0.4
Riverhead (P)	2 750	1914	1.0
Rochester (P)	32 000	——	4.8
Rouse's Point	1 640	——	0.1
Seneca Falls	6 590	1912	2.0
Sidney (P)	2 510	1904	0.3
Sonyea	1 500	1915	1.0
Stamford (P)	1 000	1899	0.2
Suffern (P)	2 660	1911	0.4

TABLE 9. — *Continued.*

NEW YORK. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Tarrytown	5 600	——	2.5
Valatie (P)	1 220	1894	0.2
Walton (P)	3 100	1914	1.5
Waterford	3 250	1914	2.0
Watertown	26 730	1902	10.0
Watervliet	15 070	1915	4.0
Watervliet Arsenal (P)	1 500	1900–1908	0.4
Williamson	1 500	1915	0.5
Youngstown (P)	1 000	1915	0.3

NORTH CAROLINA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Albemarle	2 120	1913	0.5
Asheville	20 160	1894	1.0
Bessemer City	1 530	——	0.6
Biltmore (P)	1 500	1897	0.5
Canton (P)	1 390	1915	0.5
Charlotte	34 010	1896–1905	5.5
Concord	8 710	1911	0.5
Durham	22 860	1916	3.0
Elizabeth	8 410	1906	0.5
Fayettesville	7 040	1911	1.0
Gastonia	5 760	1900–1908	0.7
Goldsboro	6 110	1913	0.5
Greensboro	18 390	1903	2.5
Greenville	4 100	1905–1913	0.6
Hamlet	2 170	——	0.5
Henderson	4 500	1912	1.0
Hendersonville	2 820	——	0.5
High Point	11 810	1893–1911	3.0
Louisburg	1 780	1905	0.3
Lumberton	2 230	1916	1.0
Mt. Airy	3 840	1913	0.3
Pinehurst	1 500	1911	0.5
Raleigh	19 220	1887–1913	4.0
Reidsville	4 830	1913	0.5
Rocky Mount (P)	8 050	1900–1909	1.4
Salisbury	7 150	1916	0.8
Sanford	2 280	1907	0.4
Shelby	3 130	1911	1.0
Smithfield	1 350	1912	0.3
Southern Pines	1 500	1910	0.5

TABLE 9. — *Continued.*

NORTH CAROLINA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Statesville	4 600	1912	0.5
Tarboro	4 130	1911	0.5
Waynesville	2 010	1910	0.5
Weldon	2 000	1913	0.4
Wilmington	25 750	1906–1909	4.0
Wilson	6 720	1916	2.3
Winston-Salem	29 030	1904–1910	2.5
Washington	1 500	1914	1.0

NORTH DAKOTA.

Fargo	14 330	1911	4.0
Grand Forks	12 480	1910	2.0
Minot	6 190	1910	1.0
Sykeston (P)	500	1915	0.1
Wahpeton	2 740	1914	1.0
Williston	3 120	1914	0.7

OHIO.

Akron	69 070	1915	20.0
Alliance	15 080	1913	6.0
Ashtabula	18 270	1908	6.0
Attica	———	1915	0.2
Barnesville	4 230	1915	0.5
Batavia	1 030	1899	0.1
Bellaire	12 950	1905	5.0
Bucyrus (P)	8 120	1887–1904	1.5
Cambridge	11 330	1915	2.2
Cedar Point	1 000	1913	0.6
Cincinnati	416 120	1906	112.0
Columbus	204 570	1906	30.0
Conneaut	8 320	1904–1912	1.5
Dennison	4 010	———	2.0
East Liverpool	20 390	1915	6.0
East Youngstown	4 970	1916	1.0
Elyria	14 820	1907–1911	4.0
Geneva	2 500	1902	0.7
Huron	1 760	1909	0.5
Ironton	13 150	1916	4.0
Jefferson	1 460	1908	0.8
Lakeside	750	1912	0.2

TABLE 9. — *Continued.*

OHIO. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Lorain	28 890	1906	6.0
Marietta	12 920	1904	4.0
Massillon (P)	13 880	1888	0.7
Medina	2 730	1916	1.0
Napoleon	4 010	1915	1.5
Newark	25 400	1900	2.0
Niles	8 360	1911	3.0
Oberlin (P)	4 370	1903	1.0
Painesville	5 500	1915	2.5
Port Clinton	3 310	1911	1.5
Portsmouth	23 480	1913	8.0
Rocky River	1 170	1907	0.5
Sandusky	20 000	1908–1912	10.0
Steubenville	22 390	1915	6.0
Tiffin	11 890	1913	1.0
Toledo	184 130	1909–1914	34.0
Upper Sandusky	3 780	1904	1.0
Vermilion	1 370	1904	0.3
Warren	11 080	1916	5.5
Waverly	1 800	1910	0.5
Wellington	2 130	1915	0.5
Willoughby	2 070	1914	1.0
Woodsfield	2 500	1914	0.6
Youngstown	91 650	1905–1915	28.0

OKLAHOMA.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Altus	4 820	1916	0.4
Anadarko (P)	3 440	1910	1.5
Ardmore (P)	8 620	1910	1.5
Bartlesville	6 180	1912	1.0
Blackwell	3 270	1909	1.0
Caddo	1 140	1915	0.3
Chickasha	10 320	1910	1.0
Claremore	2 870	1911	1.0
Clinton	2 780	1910	0.8
Durant (P)	5 330	1911	1.0
Guthrie	11 650	1910	1.5
Hominy	500	1914	0.1
Henryetta	2 230	1916	1.0
Holdenville	2 300	1912	0.5
Muskogee	25 280	1912	12.0

TABLE 9. — *Continued.*

OKLAHOMA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Oklahoma City	64 210	1906	8.0
Pauls Valley	2 690	1908	0.5
Pawhuska	5 030	1907	0.5
Pryor (P)	1 800	1912	0.7
Sapulpa	8 300	1911	2.0
Shawnee	12 470	1904	1.5
Stillwater	3 440	——	0.5
Tishomingo	1 410	1911	1.0
Wagoner	4 020	1914	1.0
Yale	500	1915	0.1
	OREGON.		
Albany	4 280	1912	3.0
Arlington	500	1911	0.2
Eugene	9 010	1906–1911	4.0
Hood River (P)	2 330	1913	0.1
McMinnville	2 400	1911	0.5
Milton	1 280	1915	1.0
Oregon City	4 290	1910	1.5
Roseburg (P)	4 740	1907	1.0
Springfield	1 840	——	1.0
Wauna (P)	500	1913	0.1
	PENNSYLVANIA.		
Arnot	2 500	1890	0.1
Beaver Creek	3 460	1910	0.6
Beaver Falls	12 190	——	8.0
Berwick	5 360	1913	2.0
Bethayres	400	——	1.5
Bethlehem (P)	12 840	1912	0.6
Bloomsburg	7 410	1912	3.0
Bristol	9 260	1906	2.0
Brookville	3 000	1910	1.0
Brownsville	2 320	1915	2.0
Butler	20 730	1905	5.0
California	2 230	1914	0.5
Cambridge Springs	1 510	1908	1.0
Canonsburg	3 890	1910	2.0
Canton	1 640	1899	0.5
Carlisle	10 300	1911	2.0

TABLE 9. — *Continued.*

PENNSYLVANIA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Catasauqua	8 650	1914	2.0
Centerville	1 410	1916	0.3
Charleroi	9 620	1910	3.0
Chester	38 540	1916	12.0
Clarion	2 610	1900	0.5
Columbia	11 450	1904	2.0
Connellsville (P)	12 850	——	2.0
Danville	7 520	1914–1915	1.5
Eaglesmere	200	——	0.5
East Greenville	1 240	1912	0.3
Ellwood City	5 200	1909	3.0
Emlenton	1 110	1915	1.0
Ernest	500	1907	0.1
Erie	66 530	1912	24.0
Franklin	2 100	1908	2.0
Freeport	2 250	1908	0.5
Gettysburg	4 030	1912	1.0
Greenville	5 910	1913	1.0
Harrisburg	64 190	1905	15.0
Henderson	6 000	——	1.0
Holmsburg (P)	20 000	1906	3.0
Hummelstown	2 130	1908	2.0
Indiana	5 750	1906	1.2
Iselin	——	1905	0.1
Jersey Shore	5 380	1915	1.0
Kittanning	4 310	1908	2.0
Latrobe	8 780	1912	3.0
Lebanon	19 240	1910	3.0
McDonald	2 540	1914	0.7
McKeesport	42 690	1908	6.0
Marianna	1 360	1911	0.5
Masonton	1 000	1911	0.5
Mechanicsburg	4 470	1908	0.5
Media	3 560	——	1.0
Middletown	5 370	1910	1.0
Midland	1 240	1914	0.8
Monessen	11 780	1909	1.0
Monongahela	7 600	1904	2.0
Montgomery	1 480	1912	0.2
Natrona	4 800	1915	0.7
New Bethlehem	1 620	——	0.1

TABLE 9. — *Continued.*

PENNSYLVANIA. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
New Brighton........	8 330	1889	0.5
Newcastle...........	36 280	1898–	7.0
New Kensington......	7 710	1912	3.0
Newport.............	2 010	1910	0.3
Norristown..........	27 880	1915	5.4
North East (P).......	2 670	1908	0.5
Oakmont............	3 440	1914–1916	4.0
Overbrook...........	500	1895	0.3
Parker..............	1 240	1911	0.1
Phoenixville..........	10 740	1913	3.0
Pickering Creek......	1 000	1896	0.8
Polk................	2 070	1913	1.0
Pottstown...........	15 600	1908	4.0
Punxsutawney.......	9 060	1909	2.0
Quarryville..........	800	1911	0.3
Ridgeway............	5 410	1915	1.0
Riverton............	———	1909	1.5
Royersford...........	3 070	1895	0.7
Sayre...............	6 430	——	0.2
Scranton............	129 870	1909	6.0
Sharon..............	15 270	1915	6.0
South Bethlehem.....	19 970	1916	6.0
South Pittsburgh.....	70 000	1907	14.0
Sunbury.............	13 770	1905	5.0
Tarentum............	7 410	1907–1914	4.0
Vandergrift..........	1 200	1899–	1.0
Warren..	11 080	——	3.0
Washington..........	18 780	1901	4.0
Waynesburg.........	3 550	1901	1.0
West Reading........	2 060	1914	0.3
Wilkesbarre..........	67 100	1895	14.0
Wilkensburg.........	18 924	1916	2.5
York................	44 750	1890	6.0

RHODE ISLAND.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Bristol-Warren.......	15 150	1912	3.0
East Greenwich (P)...	3 420	1908	1.0
East Providence......	15 810	1906–1914	3.0
Jamestown (P).......	1 180	1909	0.5
Newport.............	27 150	1910	6.0

TABLE 9. — *Continued.*

South Carolina.

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Abbeville	4 460	1911	0.5
Anderson	9 650	1910	0 5
Camden	3 570	1902	0.5
Charleston	57 830	1902–1909	6.0
Cheraw	2 870	1914	0.7
Chester	4 750	1909	0.6
Columbia	26 320	1902–1906	8.5
Darlington	3 790	——	0.5
Dillon	1 760	1909	0.5
Gaffney	4 770	1905	0.5
Lawrens	4 820	1905	0.5
Rockhill	7 220	1910	1.0
Spartanburg	17 520	——	2.0
Union	5 620	1900	1.0
Yorkville	2 330	1911	0.5

South Dakota.

Huron	5 790	1914	1.5

Tennessee.

Chattanooga (P)	44 600	1888–1893	9.0
Clarksville	8 550	1910	2.0
Columbia	5 750	1915	1.0
Dyersburg	4 150	1904–1907	1.0
Knoxville	36 350	1904–1914	8.0
Maryville	2 380	1916	2.0
Morristown	4 010	1915	1.0
Murfreesboro	4 180	1907	0.5

Texas.

Ballinger (P)	3 540	1911	0.5
Beaumont	20 640	1904	3.0
Brady	2 670	1912	0.3
Brownsville	10 520	1911	1.0
Brownswood	6 970	1914	1.0
Corpus Christi (P)	8 220	1915	1 5
Dallas	114 740	1913	15.0
Denison	13 630	1914	2.0
Fort Worth	73 310	1911	5.0
Graham	1 570	1910	0.2

TABLE 9. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
TEXAS. — *Continued.*			
Lagrange (P)	1 850	1891	0.2
Laredo	14 850	1910	2.0
Longview	5 160	1915	1.0
Paris	11 270	1909	1.0
Rosebud (P)	1 470	——	0.3
Temple	10 990	1911	2.0
Waco	35 570	1912	5.0
Wichita (P)	1 000	1904	0.3
VERMONT.			
Burlington	20 470	1908	2.5
White River (P)	2 600	——	0.1
VIRGINIA.			
Danville	19 020	1905–1915	3.0
Emporia	2 020	1909	0.8
Farmville	2 970	1907	0.5
Fort Myer	1 000	1902–1912	1.5
Front Royal	1 130	——	1.0
Manchester	14 000	1906	2.0
Martinsville (P)	3 370	1912	0.5
Newport News (P)	20 200	1906	0.3
Norfolk	67 450	1899	8.0
Petersburg	24 130	1901–1910	2.5
Portsmouth	33 190	1907	6.0
South Boston	3 520	1916	1.0
Virginia Beach (P)	500	1910	1.0
Waynesboro	1 390	1909	0.5
WASHINGTON.			
Centralia (P)	7 310	1906	1.0
Waitsburg	1 240	1906	0.5
WEST VIRGINIA.			
Benwood	4 980	1900–1906	1.5
Charleston	23 000	1906	5.0
Clarksburg	9 200	1910	3.0
Elm Grove	1 900	1912	1.0
Fairmont	9 710	1898	1.0
Franklin	——	1911	1.0
Glen Ferris (P)	200	1910	0.1
Huntington	41 520	1898–	4.0

TABLE 9. — *Concluded.*

West Virginia. — *Continued.*

City.	1910 Population.	Date Installed.	Capacity. (M.G.D.)
Kanawha	300	——	0.5
Morgantown	9 150	1899	2.0
Sistersville	2 680	1916	1.0
Weston	2 210	1913	1.0
Williamson	3 560	1911	1.0
Wisconsin.			
Appleton	16 770	1912	4.0
Marinette	14 610	1899	3.0
Merrill	8 690	1897	1.5
Kenosha	21 370	1916	8.0
Oshkosh	33 060	1916	6.0
South Milwaukee	6 090	1910	1.5
Stevens Point (P)	8 690	1899	0.5
Wyoming.			
Basin	1 000	1911	0.5
Cheyenne	11 320	1915	5.0
Powell (P)	——	1915	0.1
Worland	750	1912	0.5
Canal Zone.			
Colon (P)	——	1907	1.5
Corozal (P)	——	1910	1.0
Miraflores	——	1915	15.0
Panama (P)	——	1907	2.0

TABLE 10.

Filtration Plants in Canada.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
Alberta.			
Edmonton	1911	Rapid Sand	6.0
Lethbridge	1917	Rapid Sand	4.0
MacLeod		Rapid Sand	——
Medicine Hat	1914	Rapid Sand	6.0
Manitoba.			
Brandon		Rapid Sand	1.0
Neepaawa		Rapid Sand	0.35
Winnipeg Agr. College.	1913	Rapid Sand	1.0
New Brunswick.			
Fredericton	1912	Rapid Sand	2.0

TABLE 10. — *Continued.*

ONTARIO.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
Arnprior	1901	Rapid Sand	0.5
Chatham	1895–1913	Rapid Sand	2.0
Coburg		Rapid Sand	1.4
Deseronto	1896	Rapid Sand	0.5
Danville		Rapid Sand	0.5
Haileybury		Rapid Sand	1.0
Hamilton		Slow Sand	12.0
Kitchener		Rapid Sand	0.4
Orilla	1914	Rapid Sand	2.07
Owen Sound		Slow Sand	2.0
Perth		Slow Sand	0.5
Renfrew	1897–1907	Rapid Sand	0.7
St. Thomas	1891–1902	Rapid Sand	2.0
Sturgeon Falls		Rapid Sand	——
Thyrso		Rapid Sand	0.1
Toronto		Slow Sand	40.0
Toronto		Rapid Sand	50.0
Wallaceburg	1914	Rapid Sand	0.65
Weston	1910	Rapid Sand	0.29
Whitby		Slow Sand	0.3
Welland	1914	Rapid Sand	0.25
	QUEBEC.		
Ahuntsic	1910	Rapid Sand	0.5
Aylmer	1917	Rapid Sand	1.0
Buckingham		Rapid Sand	1.5
Cartierville	1915	Rapid Sand	1.0
Cowansville	1912	Rapid Sand	0.25
Fraserville		Rapid Sand	0.25
Laval des Rapides	1915	Rapid Sand	0.25
Longue Pointe	1911	Rapid Sand	0.75
Longueuil	1895–1913	Rapid Sand	1.7
Montreal*	1913	Rapid Sand	30.0
Point Autrembles	1911	Rapid Sand	0.25
Ste. Hyacinthe	1917	Rapid Sand	4.0
Sault-au-Recollet	——	Slow Sand	1.0
Shawinigan Falls	——	Rapid Sand	1.0
Ste. Rose	1915	Rapid Sand	1.0
Three Rivers	1909–1911	Rapid Sand	3.45
Verdun	1908	Rapid Sand	1.0
Windsor Mills		Rapid Sand	——

* Supplies Maisonneuve, Outremont, and Westmount.

TABLE 10. — *Concluded.*

SASKATCHEWAN.

City.	Date Installed.	Kind.	Capacity. (M.G.D.)
Prince Albert	1910	Rapid Sand	0.9
Saskatoon	——	Rapid Sand	4.0

TABLE 11.

LIST OF FOREIGN RAPID SAND FILTER PLANTS.

City.	Capacity in Million Gallons Daily.
East Africa.	
Lourenco Marques	0.775
South Africa.	
Kroonstad	0.66
Australia.	
Broken Hill, New South Wales	1.50
Austria.	
Trieste	5.35
Ceylon.	
Colombo	10.17
Ragama Cooly Camp	0.231
Egypt.	
Alexandria	16.00
Benha	1.00
Benhi Souef	1.00
Cairo	20.00
Damanhour	1.00
Damietta	1.00
Mansurah	1.58
Zagazig	1.7
England.	
Hamilton	2.00
Wolverhampton	1.20
York	5.40
France.	
Annecy	0.74

TABLE 11. — *Continued.*

City.	Capacity in Million Gallons Daily.
Germany.	
Posen	7.90
Holland.	
Alblasserdam	0.384
Oldenzaal	0.384
Ridderkirk	0.384
Ysselmonde	0.300
Hungary.	
Rimamurany	0.147
India.	
Bangalore	3.6
Chandernagore	0.665
Dacca	2.6
Davengeri	0.42
Dehli	1.86
Ernakulam	0.65
Erode	0.63
Hazaribagh Jail	0.28
Hubli	1.6
Jagdalpur	0.276
Jorhat	0.18
Kanchrapara	0.33
Kolar Gold Fields	2.4
Manipur	0.228
Masulipatam	1.19
Mysore	2.48
Naini Tal	0.333
Naraingange	0.66
Pudukkottai	0.228
Ramnaggar	0.398
Secunderabad	1.86
Silchar	0.353
Simla	0.58
Sylhet	0.745
Tezpur	0.276
Italy.	
Genoa	19.6
Japan.	
Kyoto	20.2

TABLE 11. — *Concluded.*

City.	Capacity in Million Gallons Daily.
Korea.	
Riuzan	1.0
China (Manchuria).	
Inkao	1.33
Norway.	
Christiania	0.2
Peru.	
Piura	0.06
Roumania.	
Galatz	1.22
Russia.	
Armavir (Caucasus)	0.37
Arsamass	0.145
Balashov	0.33
Baku-Kura	0.33
Borgom (Caucasus)	0.145
Christopol	0.33
Helsingfors (Finland)	7.26
Nizhni-Novgorod City	2.31
Nizhni-Novgorod Fair	1.32
Novotcherkask	0.44
Petropavlovsk (Siberia)	0.33
Ribinsk	0.66
Rostov-Don	3.96
Sarapul	0.33
Semipalatinsk (Siberia)	0.33
Simbirsk	0.66
Tobolsk (Siberia)	0.55
Tomsk (Siberia)	2.44
Tsaritsyn	0.97
Vladimir-on-Kliazma	0.33
Siam.	
Bangkok	8.00
Straits Settlements.	
Johore	0.553
Lower Perak	1.44
Singapore Harbor Supply	0.178
Sungei Siakup	0.245

Early Conceptions of Water Filtration.

The earliest type of water filter was a bed of porous material through which water was passed to free it of visible impurities. So far as its relationship to disease prevention is concerned, filtration of municipal water supplies is an art which has been developed within the past thirty years. Some of the ancients had vague ideas of its hygienic usefulness, but for the most part such conceptions grew out of an apparent desire to obtain clearer or cleaner water. Although the germ theory of disease was not advanced until 1849, and although the idea that disease in any form could be water borne had its practical genesis at about that time, it seems certain that some of the early philosophers came to the conclusion that something more than mere clarification was effected by water filtration. Thus we find in "*Ousruta Sanghita*," a book of medical lore written in Sanscrit probably some four thousand years ago, the statement: "It is good to keep water in copper vessels, to expose it to sunlight, and filter through charcoal." The writings of Hippocrates and Pliny also disclose facts which indicate clearly that the ancients had some regard for pure water and a distrust in polluted waters.

Similarly, William Walcott's patented process (1675) for "making water corrupted fit for use" undoubtedly aimed at something more than mere clarification, but it is equally certain that the inventor did not know just what; and in 1790 Johanna Hempel patented a contrivance for filtering water, using sand, gravel, and pulverized glass as the filtering media. It was not until 1829, however, that the first municipal water filter of which there is comprehensive record was built by the Chelsea Water Company at East Chelsea, London, in compliance with the recommendations of the Royal Commission on the Metropolitan Water Supply. This filter was designed to operate merely as a mechanical strainer to effect clarification, although it is significant that in the same year that this filter was built, typhoid fever was recognized as a specific disease. The germ of that disease was not discovered until 1880, some fifty years later, and it was not well understood until 1884, or some thirty-three years ago.

About twenty years after the construction of the East Chelsea filter, the British Empire was visited by a severe cholera epidemic,

and at about the same time the theory was advanced by an English scientist that cholera was a water-borne disease and that the general cause of the epidemic could be traced to the polluted water supply. Three years later (1852) came the first really important step in water filtration history. This took the form of an act of Parliament which made compulsory the filtration of the entire water supply of the Metropolitan District of London.

In 1883 Koch discovered the cholera spirillum in Calcutta water, and in 1889 Brouardel attributed 90 per cent. of all cases of typhoid fever to water.

As late as 1892, or twenty-five years ago, the hygienic efficiency of water filters of the slow sand type was seriously questioned by a large number of medical authorities and engineers. Their arguments against filtration were based very largely upon such occurrences as the outbreak of typhoid fever in that portion of Berlin, Germany, which was supplied with filtered water from the old Stralau works. Many sanitarians did not hesitate to express the conviction that filtration of impure water was an ineffective safeguard against water-borne diseases, and altogether improper, and that public water supplies should be drawn only from pure mountain streams and ground waters. The abandonment of filtered Thames water in favor of water from mountain streams was strongly advocated for London, and the current literature of that day showed a preponderating tendency against filters in general. At this date, however, the great majority of sanitarians in the civilized world are advocating filtration. In Germany, the filtration of surface water supplies has been almost uniformly compulsory for over twenty years, and impounded unfiltered supplies are found in but few important cities.

While practical modern water filtration, if we may use the term, sprang into existence with the construction of the small East Chelsea filter in 1829, and while the art developed slowly in England and on the Continent during the ensuing sixty years, it remained for the stupendous cholera epidemic in Hamburg in 1892, and the happy experience of Altona, the sister city of Hamburg, to stamp indelibly on the public mind the conviction that impure water is responsible for much of the public sickness, and to furnish unmistakable proof of the efficacy of water filtration in making

polluted water safe and minimizing the dangers invariably arising from the consumption of such waters. Actually, then, water filtration as an accepted science, and the important developments therein must be considered as about twenty-five years old or less.

It is also well known that as late as 1885, judged by comparative chemical analysis of raw and filtered water, the result was not at all favorably considered by sanitarians, as the purification effected by filtration, according to the standards of that time, was practically negligible. It is to be noted that in that day organic matter, whether living or dead, was believed to be the chief cause of water-borne disease. One of the most important factors in advancing the knowledge of water filtration at that critical period was the exhaustive work of Prof. Percy F. Frankland, who, in 1885, by applying the then modern methods of bacteriological analysis to water filtration, showed that while, from a standpoint of removal of the chemical constituents from water, filtration was a disappointment, it was a marked success in the removal from water of bacterial life.

It naturally took years, indeed generations, to bring matters to this sort of a head. Furthermore, there are to-day some sanitarians who consider water containing large amounts of organic matter as seriously affecting the purity and wholesomeness of the water regardless of how pure it may be bacterially, but the great majority now agree that, with a few unusual exceptions, it is the bacteria of disease-producing proclivities in water that determine its unwholesomeness. Finally, it is only during the past twenty-five years that water filtration has had a sound accredited standing. Frankland proved its bacterial efficiency thirty-two years ago, in 1885, as did the Massachusetts State Board of Health, and Continental investigators during the decade immediately following. It is also true, whether or not filtration was generally accepted as a safeguard against the dangers of impure water, that twenty-five years ago filtered water supplies were furnished to a total world population of 20 000 000, of which fully 99 per cent. were located in Europe and other foreign countries and about 1 per cent. in America. In 1917, however, 20 000 000 people are supplied with filtered water in North America alone, although fifteen years ago less than 2 000 000 were so supplied.

Theory and Practice in Water Filtration.

There are but two methods of filtration with records of practical accomplishment in the purification of municipal water supplies. These are commonly known as the "Slow Sand Method" and the "Rapid Sand Method." The former first appeared in the field, and the latter made its first official appearance in 1885. There were failures and indifferent successes, of course, but the early history of all accomplishments is freely dotted with such mishaps.

The success attending the use of slow sand filters in foreign countries is largely attributable to the fact that the waters upon which they operate are almost uniformly clear, that is, relatively free from suspended matters. Long years of study have proved that a slow sand filter, *per se*, cannot efficiently and economically purify a muddy water But this was not understood in the early days of filtration history, and when, in 1866, Mr. James C. Kirkwood was sent to Europe by the city of St. Louis to investigate water filtration practice, he returned with the recommendation that a slow sand filter be built for the purification of the Mississippi River supply for that city. His recommendations for St. Louis were not adopted, however, and fortunately, too, for none of the purification plants in Europe which came under Mr. Kirkwood's observation had a water to treat which in its physical characteristics was in any way similar to the Mississippi River. A few years before Mr. Kirkwood's death, however, the first slow sand filter in America was built at Poughkeepsie from plans prepared by him. The Hudson River water is not in the same class, physically, as the river waters of Western Europe, however, and material changes have since been made in the original plant and in its mode of operation. Plants of a type similar to the one at Poughkeepsie were built somewhat later at Lowell, Mass.; Columbus, Ohio; and Toledo, Ohio, but all failed of the purpose for which they were intended.

Scientific Investigation of Water Filtration.

The earliest investigations on slow sand filtration were conducted at Boston, Mass., and Louisville, Ky. Then followed the inauguration, in 1887, of the classic investigations of the Massa-

chusetts State Board of Health at Lawrence, Mass. These latter investigations were followed by the construction, in 1892–1893, of the Lawrence city filter for the purification of the badly polluted Merrimack River water, and the decision to build this filter doubtless was hastened by the Hamburg epidemic of 1892 and the appearance of cholera in New York Harbor in the same year.

Between 1887 and 1903 the water filtration experiments at Lawrence were confined to slow sand filters, but in the latter year a small gravity filter with a superficial filtering area of about four sq. ft., and containing 21 in. of relatively coarse sand (effective size 0.71 mm.), was put into operation as a rapid sand filter. The filters of the rapid sand type tested at the Lawrence Experiment Station since 1903 were as small as the first one (No. 216) or smaller.

Since 1903, the experiments at Lawrence have also covered slow sand filter operation, modified by the use of coagulating chemicals and with the allowance of a supplementary period of coagulation and sedimentation prior to filtration.

The first comprehensive tests of the rapid sand process of water filtration were conducted at Providence, R. I., in 1893–1894. Much more exhaustive experiments were started in the winter of 1895 at Louisvillle, Ky., continuing through the better part of two years thereafter. Similar investigations were carried on at Pittsburgh, Pa. (1897–1898); Cincinnati, Ohio (1898–1899); Washington, D. C. (1899–1900); New Orleans, La. (1900–1901); Harrisburg, Pa. (1903–1904); and elsewhere. Aside from the aid they rendered in the solution of the local problems, these carefully conducted investigations, which cost hundreds of thousands of dollars, more than anything else served to establish on a sound footing the entire reliability of the rapid sand process of water purification. These experiments were all conducted at a critical period in the history of this process, and the basic principles of the method were fully tested and proved.

The reports published upon the results of these various investigations were followed by a decade of extreme activity in filter construction. Between the dates 1900 and 1910, the decade in question, the number of people supplied with filtered water in the United States increased from 1 860 000 to 10 805 000, or nearly

sixfold. Of this increase, rapid sand filters provided 61 per cent. and slow sand filters 39 per cent. This was the most notable period of slow sand filter construction in the history of slow sand filtration in America. Since 1910 there have been but few important additions to the list of filters of this type built in this country. Rapid sand filter construction has steadily grown, however. Whereas between 1900 and 1910 new installations were made at the annual average rate of 78 million gallons daily filtering capacity, since 1910 the average annual rate of construction has been 139 million gallons of daily filtering capacity. The average rate of new slow sand filter installation since 1910 has been 13 million gallons daily capacity annually. The contrast is sharp.

Principal Differences between Rapid Sand Filtration and Slow Sand Filtration.

The essential differences between the rapid sand and slow sand processes of water purification lie in the character of the preparatory treatment given the raw water prior to filtration, the size of the filter units, the size of sand grains making up the filter bed proper, the rate at which water is passed through the filter, the kind of " head " used to force the water through the bed, and the manner in which the beds are cleaned.

Both types of filters are composed of sand, and consequently, so far as strict nomenclature is concerned, they are both sand filters. The normal slow sand filter is operated at a rate about one fortieth of that employed in a normal rapid sand filter, thus properly giving to each their distinguishing names of slow and rapid sand filters.

The slow sand filter is cleaned by scraping off the top layer of clogged material, washing and replacing the sand removed with this material. The rapid sand filter is cleaned by introducing filtered water through the strainer system at the bottom of the bed and allowing the dirt which has accumulated in the filter to flow off to the sewer through gutters located near the surface of the sand bed.

In the original slow sand filters the water was applied directly to the sand bed without any preparatory treatment except that

which it may have undergone in storage and impounding reservoirs, or in settling basins. In this country such plants are found at Lawrence, Mass.; Providence, R. I.; New Haven, Conn.; and Reading, Pa. In the attempt to apply the slow sand process to the purification of muddy water it was early found necessary to make use of long periods of sedimentation prior to filtration, or to use coagulating chemicals whereby the suspended matters would be gathered together in aggregates and settled out in the coagulating and sedimentation reservoirs before the thus partially clarified water was applied to the final slow sand filters. In the rapid sand process the use of a coagulating chemical is standard procedure, and always has been. It was that feature of the process which made it patentable, and it was on this idea that the original patent covering the rapid sand filter process was granted to Mr. John W. Hyatt in 1883.

Preparatory Treatment of Water for Filtration.

Those who have studied water purification practice in connection with many types of waters have been forced to the conclusion that where the water is markedly colored, or possesses a turbidity in excess of thirty parts per million (0.0039 oz. per gallon), or where there are sharp fluctuations in the character of water ordinarily but slightly colored or turbid, rapid sand filters are best adapted to its purification. This does not mean that just as good or better results may not be obtained with a rapid sand filter as with a slow sand filter in the treatment of waters which fall within these low limits of imperfection. The practice of years has virtually fixed these limits for slow sand filters. In these days where final sterilization of filter effluents is so largely practiced, and should be the uniform custom, the decision as to whether slow or rapid sand filters should be adopted for the solution of a given water problem should rest upon the proposition as to which process will yield a filtered water of satisfactory physical characteristics at the lowest total cost.

The majority of our American rivers are in the muddy water category; that is, while perhaps for a considerable part of the time the water may be relatively free from turbidity, much of the time it is heavily charged with suspended matters washed into it by rains

or melting snows. This is one excellent reason why slow sand filters have not been so widely used as rapid sand filters, and why the largest slow sand filter installations in this country have failed as such, and have undergone radical modification in their physical makeup and in the mode of their operation.

Many American streams and lakes are relatively clear but heavily colored by vegetable stains. Decoloration by exposing the water to the sun's rays is not particularly effective, and is patently unreliable, since the sun cannot be expected to shine every day, nor but a part of any day. Then, again, sun bleaching is actively felt for a depth of not more than about one foot beneath the surface, and a month's exposure of such a shallow layer of water to the sun's rays will effect decoloration only to the extent of about 20 per cent.

Filtration of colored water through clean quartz sand will not effect measurable decoloration, and it is well known that, without the aid of a coagulating chemical, slow sand filters will not consistently remove from water more than about 20 per cent. of the dissolved color. The most practical, effective, and satisfactory method of water decoloration of which we now have knowledge is coagulation followed by rapid sand filtration. The author believes he has ample grounds for this statement, not the least being the conclusion of Mr. Allen Hazen, in his book, " Clean Water and How to Get It " (1914, pp. 95–96):

> " Sand filters are used in connection with various preliminary treatments, but, generallly speaking, they are adapted to treating only such waters as are capable of being purified in that way without any preliminary treatments, or with only rough and inexpensive treatments. If water ordinarily requires coagulation, then, as a rule, it will be better to make the coagulation thorough and use mechanical (rapid sand) filters for the final treatment."

Except at the expense of much space, and by perhaps encroaching unduly on the subject of slow sand filtration, which is to be discussed by Mr. Goodnough, the author cannot well detail the departures from this important conception in filter practice which have been made at Albany, N. Y.; Philadelphia and Pittsburgh, Pa., and elsewhere. The slow sand filters alone failing efficiently and economically to purify the waters of the Hudson, Schuylkill,

Delaware, and Allegheny rivers, highly expensive preparatory treatments like pre-filtration, or coagulation followed by pre-filtration systems, were later added to the plants as originally planned in order to get satisfactory effluents from the final slow sand filters. Mr. Goodnough doubtless will discuss thoroughly this phase of modified slow sand filter practice.

In rapid sand filtration a coagulating chemical, usually aluminum or iron sulphate, is used. The coagulant, on being added to water, is rapidly and completely decomposed by the alkaline compounds naturally present in the water. Ordinarily this alkalinity is due to dissolved carbonates and bicarbonates of lime and magnesia. Where aluminum sulphate is used, the sulphuric acid portion of the coagulating chemical displaces the weak carbonic acid of the alkaline compounds, and as a result, soluble sulphates of lime and magnesia are formed, and equivalent amounts of carbonic acid and alumina are liberated. The latter unites with the water and forms the white, insoluble, and gelatinous precipitate known as aluminum hydrate, which has the property of massing together the various suspended impurities and drawing out of solution the dissolved color which the water may contain. These aggregates of coagulated matter, possessing a relatively great hydraulic subsiding value, settle out quickly in basins provided for the purpose. The partially clarified water then flows to the rapid sand filters.

The prior removal of suspended and dissolved impurities in this way relieves the rapid sand filter of much of its burden, and it is thus enabled to continue in operation for a correspondingly longer period of time without becoming clogged. Delayed coagulation following the addition of the chemical to the water, and subsequent after-coagulation in the filters themselves, is also guarded against. It is important that the period of coagulation and sedimentation prior to filtration be long enough to insure thorough coagulation and the removal of the bulk of the coagulated matters, but it should not be so long as to allow the removal of too much of the coagulated floc, the presence in the water applied to the filter of a minor part of which is essential to the efficient performance of the filter. This is particularly true in the case of rapid sand filters of the gravity type, although there

are some rapid sand pressure filters operating efficiently on relatively clear waters where no coagulating and settling basins are provided ahead of the filters.

Coagulants are also used in some of the modified slow sand filter processes. In India, Japan, and elsewhere abroad, aluminum and iron salts are employed in the pre-treatment of water for filtration through slow sand filters. In America, coagulation forms an integral part of such modified slow sand systems as those at Albany and Poughkeepsie, N. Y.; Springfield, Mass.; Philadelphia, Pa.; Washington, D. C.; and Indianapolis, Ind. Where coagulants are thus used, and the water is better prepared for filtration, it has been found that slow sand filters can be operated at much higher rates of filtration than those normally employed. Such increases in the rate of operation of slow sand filters, made possible by the use of coagulants in the pre-treatment of the water, are in the nature of a step toward unification of the two leading filtration methods now existing, the basic principles involved in both processes being the same under these circumstances.

High rates of filtration in slow sand filters invite trouble through deep penetration of suspended matter into the filter bed, however, and this is almost inadmissible in such filters, tending as it does to produce unequal rates of filtration in different parts of the bed, and creating a factor of abnormal cost and difficulty when the beds are cleaned. Conversely, such penetration of coagulated matter into the rapid sand filter bed is not a detriment. This whole question of penetration will be further discussed beyond.

Size and Equipment of Filter Units.

Up to 1900 it was the practically uniform custom to build rapid sand filter tanks of wood or steel, the filters having unit filtering capacities of about two thirds of a million gallons per day. With the construction of the 32 000 000-gal. rapid sand filter plant at Little Falls, N. J., in 1902, tanks of rectangular concrete construction came into use, and have grown in popularity since that time. The Little Falls filter plant is composed of thirty-two rectangular concrete filter units, each having a capacity of one million gallons. The largest rapid sand filter units are those at Cincinnati, which are roughly four times the size of the Little Falls units.

The early filter tanks of wood or steel were circular in plan. Some of them were divided into two compartments, the upper compartment containing the filter bed and the lower compartment serving as a coagulating basin. The strainer manifold system was situated on the upper side of the floor separating the coagulating compartment from the filter bed, on which the latter rested. In other types of gravity filter tanks the coagulating compartment was omitted, and coagulation and sedimentation carried on in detached basins. These are known as low type filters; the others, as high type filters.

For washing the filters, provision was made for forcing filtered water in a reverse direction through the strainer system on which the filter bed rested. During washing operations in some filters, agitators in the shape of iron teeth extending vertically from a revolving horizontal arm served to thoroughly mix the sand while the wash water was flowing through it, thus loosening up the bed, breaking up clogged masses, and freeing the sand of the accumulation of foreign matters removed from the water. In other types of filters the agitators were eliminated, compressed air being applied to the bed in the same manner as the wash water. Features in connection with filter washing will be discussed beyond, under a specific heading.

It may not be out of place to point out here that slow sand filters are usually constructed in units of about one acre or less in area, and that from such filters a daily yield of 3 000 000 gal. per acre is obtained, whereas from the same area of rapid sand filters 125 000 000 gal. of filtered water is secured.

The Operation of Filters, with Particular Reference to the Rate of Filtration, the Use of Negative Head, and the Penetration of Suspended Matter into the Filter Bed.

The sand comprising the filter bed proper in slow sand filters is relatively somewhat finer and less uniform in size of particles than that employed in the rapid sand filter. As filtration of impure water through a slow sand filter proceeds, there accumulates on the immediate surface of the filter a gelatinous film of organic and mineral matter. This film when formed serves to increase

materially the efficiency of the filter. With its integrity to be maintained continuously, it is obviously necessary that the rate of passage of water through it be kept practically uniform, and that it be not so high as to allow the passage of the accumulated matters materially below the surface of the sand layer. If deep penetration occurs in a slow sand filter, great difficulty is experienced in scraping off the dirty stratum, and the process is not only difficult, but costly as well. This is readily understood when it is stated that for every inch scraped from the surface of one acre of slow sand filter, 134 cubic yards of material are removed.

In slow sand filters, only positive head is utilized to force the water through the filter. By positive head is meant that head afforded by the depth of the column of water standing over the surface of the filter bed. Negative heads cannot be used in the operation of slow sand filters. By negative head is meant any head in excess over that corresponding to the depth of the column of water standing over the filter surface.

As filtration through a slow sand filter proceeds after the positive head has been exhausted and negative head is being utilized, the latter, which is analogous to suction, reduces the pressure on the water within the sand layer to a point where the water will give off air and this air will collect in the interstices of the sand layer. These accumulations of air increase the frictional resistance in the filters so rapidly that only a comparatively small quantity of water can be filtered after the loss of head equals the positive head or depth of water above the sand.

With rapid sand filters, these basic principles in the operation of a slow sand filter are directly reversed. The sand composing the filter bed proper is made up of coarser grains, and the size of these sand grains is more uniform. It follows that the frictional resistance to the passage of water through such a bed is lower than in the case of slow sand filters composed of relatively finer sand of lower uniformity in size of particles. Whereas in the latter type of filters the active filtering stratum is immmediately at the surface of the sand layer, and where deep and irregular penetration into the sand layer of suspended matters is inadmissible, in rapid sand filters the zone of filtering activity is not only at the immediate surface, but extends for a foot or more into the bed, due to pene-

tration of the foreign suspended matters in the water deep into the surface layers of the filter itself.

The rapid sand filter may be operated efficiently on either positive or negative head; in fact, the outlet piping of most rapid sand filters is so arranged as to allow of the utilization of the latter; whereas, in the slow sand filter the use of negative head results in the separation of air from the water through the formation of a partial vacuum directly beneath the clogged surface layer, and this increases the frictional resistance to the passage of water through the filter and thus sharply diminishes its filtering activity. In a rapid sand filter, however, when the loss of head enters the field of negative head, and a partial vacuum is formed beneath the clogged surface layer, the rapid passage of the water through the filter, amounting to practically forty times the velocity of the passage of water through a slow sand filter, and the exit of this water through the outlet pipe produces in effect a suction action on the sand layer itself.

Since in slow sand filters the rate at which water is passed through the sand layer is very low, the filtering material in such a bed naturally is not so closely compacted as is the case where the rate of passage of water through the sand layer is much higher than this, as is the case in rapid sand filter operation. Compacting in a filter bed is an important factor. If it is very great, the bed offers increased resistance to abnormalities in the rate of passage of water through it; the bed is hard, and the sand grains are closely packed together. In a rapid sand filter such is the condition.

The compacting of sand in a filter bed is partly due to pressure. The lower layers of a tank full of sand sustain greater pressure than the upper layers, owing to the weight of the sand above and to the weight of the water in and above the sand. It is, therefore, easily seen that the pressure increases downward, and there must also be an increasing compactness of the sand grains downward due to this pressure. Compacting of sand is also due to the velocity of the flow of water through it. The greater the velocity of flow of water through a sand layer, the greater is the tendency to rearrange the particles by washing the smaller particles downward and thus fill up the interstices lower down. The velocities of flow of water

through a slow sand filter are low, and there is comparatively little disturbance of the sand grains, but in a rapid sand filter the velocities are some forty times higher and the disturbance is bound to be much more marked.

Positive head alone, due to atmospheric pressure, plus the weight of water in and above the sand layer, adds a certain amount of pressure, but the pressure on the plane of maximum resistance is the total head, and this pressure keeps increasing as the loss of head increases. It makes no difference when the total loss of head passes the positive head point and enters the field of negative head. With airtight clogging of any stratum in the sand bed, there will be no compacting of the sand layer except that due to velocity. But increased pressure or suction produces an increased velocity of flow of water through the voids, and this increased velocity probably has some tendency to rearrange the sand grains.

To take a concrete example of compacting in a sand filter, if we loosely pour sand into a receptacle containing water, the sand obviously will settle to the bottom, one grain resting against another. It does not matter how deep the water is into which the sand is poured. If the receptacle is not shaken, more water could be added and no increase in compactness would result. The reason for this is that each individual grain of sand would be under more pressure the greater the depth of the water, but as this pressure is equal in all directions, it has no effect on compacting. Now make an opening in the bottom of the receptacle below the sand and let the water flow downward by gravity through the voids of the sand. The friction of the flowing water against the sand grains pulls them together more closely, compacts them physically, and at the same time rearranges the particles so that the fine fill into the voids of the coarse. This makes the total voids less, and as a consequence the velocity of flow through the bed becomes greater. This produces more compression and more rearranging.

An interesting summation of the action of slow sand and rapid sand filters when operating under positive and negative heads is contained in the report of Mr. George W. Fuller on the tests conducted at Cincinnati in 1898–1899. On pages 364–366 of this

report Mr. Fuller states that successful use was made of negative head in connection with the operation of the rapid sand filter, but that slow sand filters failed when operated under negative head. Mr. Fuller says in this connection:

"In slow sand filters, the section of maximum frictional resistance is always at and just below the surface of the sand layer. Accordingly, when the acting head exceeds the depth of water above the sand, there is a united clogging action at this portion of the filter, due both to suspended matters removed from the water and the air evolved from it. As a result of the combined action, the yield of water after this time is very small.

"But in rapid sand filters of this construction the section of maximum frictional resistance is at the strainers, located at the bottom of the sand layer, until the filter has ordinarily been in operation for a large percentage of the length of the run between washings. Furthermore, the clogging at the surface is relatively much slower than in the case with slow sand filters, because the higher velocity in the rapid sand filters carries considerable portions of the suspended matters further down into the sand layer. Consequently we find primarily that in rapid sand filters negative heads with the evolution of air do not occur until the acting head has reached the depth of water above the sand plus the thickness of the sand layer. For some distance beyond this the acting head can be carried before the section of the filter near the surface of the sand layer becomes the one maximum frictional resistance. Until this time arrives, negative heads evolve air in rapid sand filters at the bottom of the sand layer (which is kept from rising apparently by the velocity of flow), and thus defer the time when suspended matters from the water and from the evolved air combine at the same portion (upper) of the sand layer to cause very rapid clogging."

With further reference to the results of the Cincinnati tests, it appears that by taking the results of representative runs on the rapid sand filter during the months of September, October, and November, 1898, with the total available positive head (Fuller's definition) of 4.5 ft. above the strainer system acting, less than one third of the total yield of the filter between washings was obtained, over 70 per cent. of the total yield of filtered water being obtained while the 5.5 ft. of negative or suction head below the strainer system was being utilized.

These data are of particular significance. When a certain

point is reached in the frictional resistance offered to the flow of water through the sand layer, the accumulation at the surface of the sand layer breaks under the suction action, allowing much of the accumulated matter to pass farther down into the bed. This occurrence may be repeated several times, causing the whole bed to act as a filtering medium instead of the surface only, as is the case in slow sand filters. When the original clogged layer at the actual surface of the sand layer is first broken, a new clogged layer begins to form underneath it, and this explains the striking yields of the filter when operating under negative head as referred to above.

The employment of a down draft pipe in connection with the slow sand filters, whereby use might be made of negative head, was not a success because of the fact that the slow sand filter became clogged with air. In regard to this point Mr. Fuller had the following to say in the Cincinnati report, page 146:

"The reason of this was that the negative head (suction) reduced somewhat the pressure upon the water, which during much of the time is saturated (practically speaking) with air, thus causing the air to separate out gradually from the water as it becomes supersaturated at the reduced pressure. This separation of air took place for the most part at and just below the section of maximum frictional resistance, which of course is at the surface of the sand layer. In consequence of the gradual separation and accumulation of air at this portion of the sand layer, it was found that the filter became clogged at a very rapid rate, comparatively speaking; and of the total quantity of filtered water with 13 ft. of head, only about 20 per cent. of the volume was obtained with the 9 ft. of negative head. As the filters grow older it is probable that this percentage would be smaller."

In connection with the failure to utilize negative head to advantage in the operation of slow sand filters, it seems clear that the reason for it is that the air drawn out of the water during its passage through the sand layer remains beneath the plane of maximum resistance or elsewhere within the bed; and that under the low velocity of flow of the water through the filter it is not carried downward and out of the outlet pipe, but remains in effect to air bind the bed. In the operation of a rapid sand filter it is always feasible to utilize negative head, for the reason that while air is separated out of the water during its passage through the filter it

does not become air bound. This is so because, under the high velocities of flow of water through a rapid sand filter, a large proportion of the air is drawn away from the plane of maximum resistance, wherever it may be at any particular time, and is carried down and out of the outlet pipe. It is this suction action and high velocity of flow of water through rapid sand filters which gives to the effluent a milky appearance in many cases due to the air bubbles that are carried out of the outlet pipe with the filtered water.

When the negative head is used in connection with a slow sand filter, and this filter becomes clogged and is put out of service for cleaning, when the clogged surface layer is scraped off it is found that the use of negative head has caused a release of air from the water and that the air upon breaking through badly disturbs the clogged surface layer of the sand. As has been repeatedly stated, air is drawn out of the water when passing through rapid sand filters, but the high velocities of flow of the water carry the air downward and out of the filter for the most part. This is one of the agencies which are instrumental in prolonging the runs between washings. Owing to the fact that the water is well coagulated before its application to the rapid sand filter, the particles of the sediment layer which ultimately pass further down into the sand bed are large enough to be caught and retained within the bed. The same would not be true of a slow sand filter operating on an uncoagulated water. Furthermore, it is permissible to allow a rapid sand filter to become clogged at great depth, because the whole bed is easily washed in place by a reverse current of water. In a slow sand filter the deep penetration of mud is not permissible, for such filters are cleaned by actually removing the sediment layer from the surface of the bed. If deep or uneven penetration of suspended matters into the bed occurs, it is necessary to remove a deep surface layer. This increases the cost of operation proportionately, and is by no means a small item in the total cost.

Slow Sand Filter Cleaning.

Water filters eventually become clogged by the foreign matters contained in the water applied to them, which accumulate on and

beneath the surface of the sand layer. Slow sand filters are ordinarily cleaned by scraping off the clogged surface layer, although attempts have been made to wash the beds somewhat after the manner followed in cleaning rapid sand filters. The best known among such attempts are the so-called "Brooklyn" and Blaisdell methods.

The former method was first used in 1905 at the Hempstead filter plant by the New York City Department of Water Supply, Gas, and Electricity. The plan involved what practically amounted to surface flushing, the clogged surface of the filter bed being raked over while a shallow stream of water was run over the surface by sections temporarily formed by boards set on edge and driven into the sand, thus forming a sort of flume having a width of about ten feet. After cleaning one section, the boards were moved to a new position. This scheme has been tried also at the Torresdale plant in Philadelphia, and elsewhere, but has not been very generally used.

The Blaisdell method involved the use of a machine which traveled on overhead tracks over the surface of the filters. This machine was first tried out at Yuma, Ariz., in 1902–03 and was given careful study at the Jerome Park test plant of the Water Department of New York City in 1907–08. A good descriptive article on the workings of this machine appeared in *Engineering News*, Vol. 59, No. 11, 1908, pp. 287, 288.

The Blaisdell sand washing machine consists of an inverted box about 4 ft. square and 2 ft. deep, containing a revolving hollow axle and a hollow head from which hollow teeth projected. In operation, the box is lowered in the water standing over the filter to the surface of the sand, and is held in position and operated from a platform above. By means of electrically driven mechanism the box can be lowered and raised and moved backward, forward, and sidewise at will. The box is made to slide over the surface of the sand at a speed of about 10 ft. per minute and at the same time the teeth are revolved, thus stirring the sand mechanically. Water is introduced into the hollow axle, head, and teeth under a pressure of 10 to 20 lb. to the square inch, and passes in fine streams into the sand. A suction pump connected with the top of the box draws away just a little more water than is

supplied through the teeth, and thus carries away and discharges to a sewer the dirt which has been stirred and washed from the sand. This method has been used in a few places but has not been generally adopted.

Another apparatus for cleaning slow sand filters is the Nichols separator, wherewith the dirty sand can be washed and restored to the bed without removing the scrapings to sand washers outside the filters.

Rapid Sand Filter Cleaning.

When the sand layer of a rapid sand filter becomes clogged, it is always cleaned in place by means of a current of water forced upward through the sand, the mud and other foreign matters which have accumulated in the bed being carried off to the sewer in gutters set near the surface of the sand layer. This has been standard procedure since this type of filter first came into use, and is one of its distinguishing features. The practice varies, however, with respect to the methods of agitating the sand layer during washing and the velocity at which the wash water is applied. This latter is governed particularly by the type of underdraining system provided. Filtered water is almost uniformly used in cleaning rapid sand filters.

In some of the early rapid sand filters, during washing operations compressed air was forced into the strainer system and escaped upward through the sand layer. This action served to loosen the bed, to break up the clogged sections, and separate the mud from the sand grains. The wash water which was next applied took up these foreign matters and carried them off to the sewer. In other filters wash water alone was used, the beds being cleaned by sections. In others (the majority of circular filters), the sand layer was stirred mechanically by rakes, while the wash water flowed upward through the bed and carried off the dirt at the surface. This is more common practice to-day in circular rapid sand filters. When the rectangular type of filter tank construction came into use in 1902 the strainer system was designed for the application of both compressed air and water, and more recently, due to the adaptation of underdraining systems of special design, the use of compressed air has been omitted and the beds cleaned by applying wash water at high velocities.

Low Velocity Filter Washing. Until the construction of the Cincinnati rapid sand filter plant, and excepting filters of the sectional wash type, rapid sand filters were always cleaned with wash water applied through the strainer system at a rate of about eight gallons per square foot per minute. This was the case whether or not any special measures were taken for agitating or stirring the sand while the wash water was being forced upward through it. Eight gallons per square foot per minute in a million-gallon filter unit corresponds to about 2 800 gal. per minute of wash water.

It was found in practice that such relatively low upward velocity of flow of water was not always sufficiently great to hold in suspension in the water above the sand and carry away to the sewer the heavy particles of mud and coagulated matter washed out of the filter. Violent agitation of the clogged filter bed prior to the application of wash water, such as that occasioned by the introduction of compressed air or the use of mechanical stirrers, served to break up the impurities within the bed into small particles, and these the wash water could carry out of the filter tank with relative ease. Even when compressed air was used to break up the bed, it was found in some cases that the subsequent addition of wash water at an upward velocity corresponding to eight gallons per square foot per minute did not always carry the impurities out of the bed, but allowed certain of the heavier particles to fall back on the sand layer, where they remained upon the surface, or sunk further into it. Particularly was this found to be a factor where the raw water was derived from swampy watersheds, and contained high amounts of dissolved color and suspended vegetable matter.

There seems to be no question about mechanical stirrers being the most effective means of agitating the sand in a circular filter. These stirrers, being kept in operation while the wash water is being applied, permit a speedy and thorough washing of a filter. Compressed air, on the other hand, cannot well be applied together with the wash water, since the whole bed of sand is kept in suspension in this manner and much of it may be lost by being carried off into the sewers with the wash water unless special sand-catching arrangements are installed over the wash water

gutters. The separate use of compressed air to break up the bed results in a satisfactory loosening action, breaks up clogged sections, and even effects some separation of the mud and other impurities from the sand grains themselves; but when the air is shut off, the heavier of these impurities fall back on the bed and have to be raised again by the inflowing wash water to the level of the wash water gutters, whence they may be carried out of the filter. While the separate use of compressed air and wash water applied at low velocity was the usual procedure with all filters of rectangular construction beginning in 1902, the feeling grew that perhaps something more than this combination was required, and thus developed the modern application of the high velocity wash idea, probably first practiced in the old type Hyatt filters of the sectional wash type over thirty years ago.

Filter Washing at High Velocity. In one of the early types of Hyatt filters the strainer system was laid out so that the bed could be washed in sections, the strainer manifold system and connecting piping being arranged so that wash water could be applied to one quarter of the filter bed area at one time. Hyatt could make use of high velocities in applying wash water to his sectional wash filters for the reason that there was no gravel layer immediately above the strainer system, the sand layer resting directly on the strainers themselves. Had the more modern type of construction been used wherein there is a shallow gravel layer separating the filter bed proper from the strainer system, the use of the high velocity wash would have resulted in unseating this gravel layer, which would then have become mixed with the sand layer, and this, of course, is not permissible.

The present type of New York sectional wash filter is an outgrowth of the original Hyatt sectional wash filter. As in their prototype of a generation ago, these filters are also arranged so that they can be washed in four sections, the supply of wash water being controlled by a valve centrally located. In a 15-ft. New York sectional wash filter, the filtering area is 176 sq. ft. Each quarter of the filter bed has an area of about 44 sq. ft. In washing filters of this type it is customary to supply wash water at the rate of 1 000 to 1 200 gal. per minute, this entire amount of water being discharged successively through the four sections.

When wash water is being used at the rate of 1 000 gal. per minute, applying this quantity of water over an area of 44 sq. ft. would correspond to a rate of wash water application of 22.7 gal. per minute per square foot of affected area. When the water is applied at the rate of 1 200 gal. per minute, this would be equivalent to a rate of $27\frac{1}{4}$ gal. per minute per square foot of affected bed area.

Cincinnati Practice. In 1903–05, when the Cincinnati filter plant was under construction, certain tests were made with an experimental filter, one of the principal objects of which was to determine the relative effect of the various methods of washing the sand and gravel of the filter bed. As a result of these experiments, which are fully detailed by J. W. Ellms in the Transactions of the American Society of Civil Engineers, Vol. LXXX, December, 1916, pp. 1342 *et seq.*, it was indicated that the most satisfactory method was that in which the wash water was forced up through the gravel and sand at such a rate that the sand was floated, thereby agitating and cleansing it in one operation.

In the Cincinnati filters, as is the case with practically all modern rapid sand filters of the rectangular type, the filter bed proper rests upon a layer of graded gravel, which in turn rests upon the strainer system proper. When wash water was applied at the strainer system under high velocity, difficulty was sometimes experienced through the unseating of the gravel layer, which thus became mixed with the sand layer above it. To obviate this undesirable feature, a screen separating the gravel and sand layers was installed in the Cincinnati filters. This screen held the gravel layer in place and made any mixing of the gravel with the sand layer impossible, no matter what velocity of entering wash water was used. This was by no means a new and novel arrangement, since the same idea was developed by John W. Hyatt in his cone valve strainer, which he covered by United States Patent No. 322,103. In this arrangement the strainer itself was filled with large shot, and this aided in the distribution of the wash water as it passed upward through it. The crown of the strainer was a perforated metal plate, and upon this plate the sand bed rested.

The essential purpose of providing a gravel layer between the

sand layer and the strainer system in any filter is to insure a more even distribution of wash water upward through the sand layer itself. This was attained by the Hyatt cone valve strainer, and the same thing was aimed at in the Cincinnati design, where the sand and gravel layers were kept apart by means of screens. This same general type of filter bottom was later adopted at Niagara Falls, Minneapolis, New Orleans, and elsewhere.

Later on, at Cincinnati, it was found that the screen separating the gravel and sand layers had pulled away from the bolts where it was attached to the ridges, and also at the ends of the tanks where there was lack of support for the wire cloth and insufficient means for fastening it. This discovery was followed by the removal of the screens separating the sand and the gravel and the use of deeper gravel layers. These gravel layers, some 14 in. deep, graded upward in size from 2-in. to ¼-in., afforded a protection against disturbances of the gravel through the application of wash water moving at high velocities and the subsequent mixing of the sand and gravel layers.

The Wheeler Filter Bottom. The next important development in a type of filter bottom which would allow of the application of wash water under high upward velocities without mixing the sand and gravel layers was the Wheeler filter bottom, which was patented by Mr. William Wheeler on August 24. 1915.

The Wheeler patent covers an arrangement of the filter floor into a series of cells, or depressions, these cells taking the form of inverted pyramids. In the lower end of each cell there is an opening. In each cell there is an assembly of pyramidally arranged spheres over the opening at the lower end. The apex sphere is heavy, is maintained in a fixed position over the opening in the bottom of the cell, and is so arranged as to receive the impact of an upward stream of water directly through the opening and distribute the same upward through the cell, compelling the passage of water between its outer surface and the walls of the cell. The apex sphere is substantially larger than the opening in the bottom of the pyramid cell, and overlies the major portion of the opening, but does not choke the outlet.

Over and about the apex sphere, and resting partly upon it and partly against the walls of the cell, are arranged four similar

spheres, and over these, and arranged in the same manner, are nine smaller spheres, all of the spheres being sufficiently large to provide water passages between them and the walls of the cell for effecting a uniform predetermined upward distribution of wash water to the filter bed above, and sufficiently heavy to remain substantially fixed against the upward flow of water past them.

In a recent article * Mr. Frank A. Barbour describes early experiences with the Wheeler bottom, and discusses in particular his observations respecting the installation at Akron, Ohio. Reciting the advantages of this type of filter bottom, Mr. Barbour lays especial stress upon its low first cost, the absence of dead spaces, the absence of metal parts subject to depreciation, and the completeness with which high wash water flows are distributed so that, with upward velocities as high as and even exceeding 4 ft. (30 gal. per square foot) per minute, there is no preceptible movement of a 6-in. gravel layer, even before the sand is placed. This gravel layer, it should be stated, consists of three layers, ranging in size from $\frac{3}{4}$ in. to about $\frac{1}{8}$ in.

A feature of interest in the operation of the Wheeler filter bottom is that the loss of head through the pyramidal pockets is less when all the concrete spheres are in place than when the pockets are empty. Experiments conducted in Jersey City by Mr. James E. Williamson disclosed as the probable reason for this the fact that, with the spheres in position, the center sphere, resting immediately above the discharge orifice at the apex of the depression, serves to increase the coefficient of discharge of the $^3/_4$-in. tube through the development of a vacuum at the point where the sphere rests on sides of the depression. Further experiments showed that when the rate of wash water application was 8 gal. per minute, the loss of head in the filter bottom, the 6-in. gravel layer and through the 30-in. sand layer, was 2.76 ft.; at 15 gal. per minute, 4.86 ft.; and at 22 gal., 7.80 ft. These figures are substantially the same as those reported for the remodeled Cincinnati filter. The greatest loss of head occurs in the strainer or floor system, the loss through the sand layer varying but little with the rate of application of wash water.

* Transactions of the American Society of Civil Engineers, Vol. LXXX, December, 1916, pp. 1411 *et seq.*

Essentials in Rapid Sand Filter Washing.

Whether low velocity washing coupled with air or mechanical agitation of the sand layer, or the application of wash water alone at high velocities is the better method, need not be discussed here. Perhaps in some localities one may be better than the other. There are certain essentials in rapid sand filter cleaning, however, which do not allow of argument. These are that, whatever the procedure followed, the gravel layer must not be unseated and mixed with the sand; the filter bed proper must be floated, and so broken up as to be amenable to thorough and economical washing; the upward flow of wash water must not be so great as to carry away with it appreciable quantities of the filter sand; and, finally, but by no means least, the foreign matters thus separated from the sand must be carried upward and out of the filter tank with the wash water.

Filter Cleaning Practice.

Violent air or mechanical agitation prior to the application of the wash water tends to thoroughly break up clogged sections of the bed and to comminute the particles of foreign matter separated from the sand. Thus the specific gravity of such matters is lessened and their flotation by the rising wash water which follows made easier. Application of wash water alone at high velocity may not break up these lumps of foreign matter into such fine particles, but the more rapidly rising column of water is expected to counteract this feature through its ability to float particles of relatively high specific gravity.

Until the rectangular filter tank came into use fifteen years ago, gravel layers, with a few exceptions, were not placed between the filter floor and the sand bed proper. The filter units were comparatively small, being seventeen feet in diameter or less. It is self-evident that to clean such filters thoroughly by applying compressed air, followed by wash water at low velocity, or by wash water alone at high velocity (sectional wash filters), or, as was the case in the majority of instances, by wash water at low velocity, the bed being stirred continuously with a rotating rake during the washing process, was not especially difficult. Circular filters

much larger than this present too many mechanical difficulties in the application of rake agitation, and out of this limitation, and a desire for space economy, grew the rectangular type of filter construction where units were built as large as 1 400 sq. ft. in filtering area.

The need of modifying existing methods of filter cleaning so as to obtain good results when washing these large rectangular units was at once apparent. Obviously mechanical rakes were not readily applicable to filters of this shape (the idea was tried without success at Louisville), and so recourse was had to the alternate use of compressed air and wash water, and later to water alone applied at high velocity.

In the early days, when only small plants of circular filters were being built, Hyatt's evident desire to overcome the necessity for mechanical agitators or even compressed air when washing filters took shape in his sectional wash filter. Careful scrutiny of his patent specifications leads to the conclusion that he was impressed by the fact that to apply the high velocity wash idea, by forcing large volumes of water through the entire filter, would lead to relatively, perhaps prohibitively, high construction costs for wash water pumps, pipes, etc.; and he aimed at securing the same result by applying wash water at high velocity to the filter bed in sections. In this way smaller pumps and discharge pipes could be employed, and in those early days a dollar to be spent for a water filter was scrutinized even more carefully than now, and that is saying a good deal. Naturally, then, the filter contractor sought every possible means of minimizing construction costs in order to make his proposition attractive. This was even more necessary then, when the filtration art was in its veriest infancy in this country, than now, when the beneficent record of water filtration is well understood.

As water filtration grew in popularity, large cities began to adopt it. Out of the demand for plants of large capacity grew the decision to build larger units. Reinforced concrete and rectangular filter tanks became the vogue, and with the construction of large plants the need of splitting hairs on the cost of wash water pumps, tanks, and delivery pipes passed into the discard. Filter floors were laid out for both compressed air and wash water application,

or for water alone, provision always being made for washing the entire bed at one time; and if the high velocity wash idea was adopted, the necessary means were provided.

Composition of the Little Falls Filters.

The 32-million gallon rapid sand filter plant built at Little Falls, N. J., was the forerunner of large water filters of reinforced concrete construction.* The filter tanks were built monolithic, in units 15 ft. by 24 ft., corresponding to a filtering area of 360 sq. ft. Each unit has a nominal capacity of one million gallons daily. The strainer system in each filter comprises a cast-iron header, oval in section, 12 by 6 in., running lengthwise of the tank in the center, to which are connected $1\frac{3}{4}$-in. cast-iron laterals, set $6\frac{3}{32}$ in. from center to center. The laterals are cemented into the header and extend to the sides of the tank, where their ends are closed with cement plugs. Into the header and the laterals are screwed strainers of the Continental type, on $6\frac{3}{4}$-in. centers. There are 1 316 strainers in each filter tank. Compressed air and water are applied through this single system of pipes, which are half embedded in the concrete floor of the filter tank.

The strainers are of brass, and in the top and sides thereof there are thirty-three $\frac{1}{16}$-in. perforations. The neck of the strainer is a $\frac{3}{8}$-in. brass tube, which extends into the cast-iron lateral to within $\frac{3}{4}$ in. of the bottom. This extension tube forms a trap when air is applied during filter washing operations, and the air passes from the lateral through a $\frac{3}{32}$-in. perforation in this extension tube, and located just below the upper wall of the cast-iron lateral.

The perforations in the strainers being somewhat larger than heretofore used, with the possible exception of the plants at Louisiana, Mo.; Middletown, N. Y.; and Cairo, Ill.,— where Mr. Robert E. Milligan initiated the idea of coarser strainers covered with gravel, — made necessary the placing of a layer of gravel over and around the strainers on which to support the sand layer and prevent it from reaching the orifices. The gravel layer in these

* "The Filtration Works of the East Jersey Water Company at Little Falls, N. J.," by George W. Fuller, Transactions of the American Society of Civil Engineers, Vol. L, p. 394, 1903.

filters is 7 in. thick and the sand layer 30 in. Gravel was selected of such hydraulic subsiding value that it would not be unseated when wash water was applied at a rate of about 7.5 gal. per square foot per minute, and of a size fine enough to prevent the sand from passing through the gravel layer.

The Little Falls plant served as the prototype for the majority of large filters built for several years after 1902, and then, perhaps as much to avoid the possibility of mixture of the sand and gravel layers during washing as for reasons of economy in construction, the now considered modern bottom, or filter floor, built in alternate ridges and furrows or as a checkerwork of square hopper-shaped depressions, made its appearance.

Development of Strainer Systems.

There probably has always existed in the minds of filter designers the conviction that the ideal filter is one which will allow wash water to be introduced at the bottom of the filter in such a manner as to insure an even upward rise over the entire horizontal plane of the filter, to avoid violent jet action, and particularly to avoid dead spaces at the bottom of the bed which the wash water would not directly reach in its upward flow through the filter. In addition to filter bottoms wherein the strainer system was arranged generally after the same fashion as in the Little Falls filters, there were numerous other types in which individual strainers played no part. Some early inventors devised filters with false bottoms, the upper sides of which were covered with perforated brass plates or wire cloth of fine mesh. Others laid out the filter floor in troughs covered with wire cloth or perforated plates, and in some filters the bottoms were composed of inverted cone-shaped depressions covered with perforated metal or wire cloth. In all such filter bottoms the perforated plates or wire cloth covering for the troughs or cone-shaped depressions were fastened flush with the filter floor, and upon this flat surface the sand bed rested.

Coincident with such designs as those just referred to were filter bottoms arranged in alternate ridges and furrows, the bottom of each furrow between two ridges being formed by perforated metal plates, sometimes two sets of such plates being fastened in the furrow, one above the other. The sand layer rested upon

these plates and upon the sloping sides of the ridges. The wash water passed upward through the perforated plates, and its flow being more or less obstructed by the filtering material was supposed to be made to flow in all directions so that, when it reached the top of the ridges, it thereafter rose through the filter bed evenly over a horizontal plane. Hyatt patented this idea in 1898.

A filter bottom somewhat similar to this, with the exception that the depressions instead of being continuous channels consisted of a checkerwork of pyramidal depressions, was built into the New Milford plant of the Hackensack Water Company in 1905. On each side of the central wash water trough, with a main effluent collector in the center, are four strainer and collector units. The lateral collectors are oval passages 4 in. wide and 5 in. high, formed in concrete blocks which are each 5 ft. by 8½ in. wide and 9 in. high. These blocks, when assembled side by side, form a strainer floor consisting of a checkerwork of hopper-shaped depressions 3 in. deep. The bottoms of these depressions are 3 in. square, and each supports a strainer consisting of a square plate of sheet brass perforated with 137 holes $\frac{1}{16}$ in. in diameter and pressed into the form of a flat truncated pyramid. Below the strainer is a pocket about $2\frac{1}{2}$ in. square, connected with the lateral collector by a piece of $\frac{3}{8}$-in. brass pipe. The strainer is fastened down with a $\frac{1}{8}$-in. brass bolt, screwed into a brass nut, set in the concrete at the bottom of the pocket. Each of the eight units of the strainer system has a central main collector to which the oval laterals connect.

The next step was to lay off the floor of the filters in ridges and furrows, the furrows being filled with gravel and arched over from ridge to ridge with wire cloth. This was the first definite step toward the modern application on a large scale of Hyatt's idea, disclosed in his sectional wash filter, patented in 1898. It was thought that the channels with sloping sides when filled with gravel would eliminate dead spaces which the wash water could not directly reach in its upward passage through the filter bed, and thus produce an even distribution of the wash water over all parts of the filter; and the screen separating the gravel from the sand would surely guard against any possibility of their becoming mixed. City filters constructed at Cincinnati, New

Orleans, Louisville, Minneapolis, Grand Rapids, Evanston, and elsewhere, between 1906 and 1914, had bottoms of this type. It is furthermore worthy of note that some years ago Mr. Ira H. Jewell brought suit against the city of Minneapolis, claiming infringement of certain patents owned by him, among these being Patent No. 649,411. In August, 1915, the United States District Court decided that the brass wire screen, such as above described, infringes Claim No. 14 of Patent No. 649,411. On appeal, however, Judge William C. Hook, of the Circuit Court of Appeals, handed down a decision in St. Paul on October 16, 1916, reversing the findings of the lower court and directing that the suit should be dismissed.

The next step and latest development of filter floor design was the Wheeler bottom, first installed in a filter of size at Akron, Ohio, in 1916.

In washing a rapid sand filter of whatever design, it is imperative that the operation be so conducted that the gravel and sand layers will not become mixed to any material extent, for reasons that are obvious. The Wheeler bottom probably comes nearer being a perfect safeguard in this respect than any type of filter floor yet devised. The filter bed must be floated, and so broken up, thus aiding in a most substantial manner the thorough and economical washing operation. When a rapid sand filter has been in operation several hours it is closely compacted and hard. It cannot be efficiently cleaned until it is well loosened and all lumps broken up. It is important that the upward velocity of the wash water be not so great as to carry appreciable amounts of sand out of the filter. Provision against this is best made by the judicious arrangement of wash water gutters, bearing in mind that a bed of sand having an effective size of .40 mm. and a uniformity coefficient of about 1.60 will rise about 8 in. when wash water is being applied at a rate of about 7.5 gal. per square foot per minute; about $12\frac{1}{2}$ in. with 15 gal. per minute, and about $16\frac{1}{2}$ in. with 22 gal. per minute.

Rate Control.

One of the cardinal necessities in filter operation is the control of the rate of passage of water through the filter. Slight varia-

tions are permissible, say within 5 per cent. limits, but sudden fluctuations much greater than this have a marked disturbing influence on the condition of the filter bed and the quality of the filtered water. Gradual variations in the rate of filtration, if relatively small, are of practically no significance, except, perhaps, where a material reduction in the velocity of flow of water will sometimes allow occluded air to pass upward and break through the most effective part of the filter bed, namely, the *schmutzdecke*, or mud layer on the surface of a slow sand filter, and the clogged stratum in the rapid sand filter. The greatest danger accompanying sudden increases in the rate of filtration lies in the shock to which the filter is subjected. The natural clogging of a water filter takes place gradually, and where the rate is practically constant the frictional resistance to the flow of water through the filter builds up proportionally. A sudden increase in the velocity of flow through the filter, caused by quickly opening the outlet, will break the filter and carry the foreign matters deep into the sand, and even completely through it. The normal functions of the filter are thereby temporarily upset, and under these circumstances the quality of the filtered product suffers marked deterioration. One would never consider it proper to increase the speed of a pump by suddenly opening the throttle. The strain would tend to injure the pump and perhaps destroy it. Suddenly increasing the rate of filtration in a filter will just as certainly be followed by unsatisfactory results.

In the early days such attempts as were made to regulate the rate of filtration were effected by hand regulation of the effluent valve.

The automatic filter controller, designed by Mr. Edmund B. Weston in 1899, was the first to justify recognition as an effective safeguard against rate fluctation, and is used successfully in a very large number of filter plants. It is a device wherein the velocity head, or an artificially created difference in head in the effluent pipe, regulates proportionately the area of a discharge orifice. There are several automatic rate controllers of the Venturi type which are widely used. A Venturi tube is placed in the effluent pipe, and beyond this is a valve whose opening is regulated by the position of a piston contained in a cylinder. A pipe connection

from the Venturi throat transmits the pressure at that point to the upper side of the piston. The underside of the piston is subject to the pressure in the pipe beyond the Venturi throat. By shifting a counterweight on a lever attached to the piston the resistance at the valve is increased or lessened as the case may be, and the flow consequently increases or decreases until a balanced condition is restored.

Red Water Troubles.

A phenomenon not infrequently encountered where a community changes from an unfiltered to a filtered supply is the appearance of iron rust in the water. Until the matter was given particular study, the use of alum salts in the purification process was thought to be responsible for this, the chemical compounds resulting from the decomposition of aluminum sulphate in water acting as corrosive agents on iron service pipes. If alum is used in excessive amounts, that is, in quantities which cannot be decomposed by the natural alkaline constituents of the water, or by alkalies artificially added to the water, — and free alum passes into the filtered water, rendering it acid,— then there is no question that such a water will exercise a corrosive action on service pipes; but where the coagulating chemical is used as it should be used, and always can be used, the employment of aluminum sulphate in water purification processes is of no significance with respect to the production of " red water " through the passing into solution of iron from pipes, with the possible exception of the added encouragement to corrosion afforded by the small amounts of free carbonic acid liberated from the coagulating chemical when decomposed in water. And even this feature can easily be nullified, practically speaking, through aëration of the filtered water.

Omitting the purely technical side of the question of metal corrosion by water,* it is well known that iron has a natural tendency to dissolve in water. Whipple (*loc. cit.*) classifies the water supplies with which red water troubles have been observed, as follows:

* In this connection the reader is referred to the following publications and to the references given therein: W. H. Walker, *Journal Boston Society of Arts*, January, 1909; G. C. Whipple, Proceedings American Water Works Assn., 1911, p. 231; R. S. Weston, Journal N. E. W. W. A., Vol. XXIX, p. 559.

Class 1. Very soft waters.

Class 2. Waters in which chlorides or the free carbonic acid are high as compared with the alkalinity.

Class 3. Very soft surface waters that are relatively high in color and contain peaty organic matter and free carbonic acid.

Class 4. Relatively soft waters, especially high-colored waters, with which sulphate of alumina is used as coagulant, but which are not overdosed so far as the alkalinity is concerned.

Class 5. Waters overdosed with sulphate of alumina so as to render them acid.

Class 6. Waters containing originally excessive amounts of iron.

The waters of Class 1 contain high amounts of free carbonic acid, often are high in chlorine, and contain considerable iron in solution. Aëration and filtration will correct the iron defects in such waters and eliminate red water troubles through dissipation of the free carbonic acid and oxidation of the dissolved iron.

Waters of the second class are found along the Atlantic coast, and also where natural salt deposits obtain. The high chlorides in such waters play an important part in metal corrosion, and they cannot be removed from water by any practical method.

Waters containing originally high amounts of iron (Class 6) can be corrected by aëration and filtration, and red water troubles due to the precipitation of the iron in pipes and domestic containers be thus nullified.

Waters which have been overdosed with aluminum sulphate so as to render them acid need no discussion. They will corrode metals and cause red water trouble, but there is absolutely no excuse for such overdosing. With a competent filter operator such a thing would not occur.

We now come finally to the waters of Class 3 and Class 4. These waters are fairly soft, contain considerable vegetable stain and peaty organic matter picked up on the watershed, and are usually high in free carbonic acid. It is desirable to decolorize such waters, and the only practical manner in which this can be done is by coagulation and filtration.

It is perfectly well known that carbonic acid dissolved in water increases the hydrogen ions present and consequently increases

its corrosive properties. The waters of the two classes under discussion naturally contain relatively high amounts of carbonic acid. The Passaic River above Little Falls contains as high as 15 parts per million, and averages 8 parts per million. Other river and lake waters draining similar watersheds contain even more free carbonic acid than the Passaic River.

Now when such waters are treated with aluminum sulphate to prepare them for filtration the natural free carbonic acid content is increased by some four parts per million to each grain per gallon of added coagulant. Doubtless this is a factor in some places in increasing the corrosive properties of the water, but an efficient remedy lies in the aëration of the filtered water whereby the bulk of all the free carbonic acid is dispelled from it. If the case is serious, the addition of alkalies will entirely eliminate the free carbonic acid, but it is a much less satisfactory remedy than aëration.

Water highly colored with vegetable stain is high in organic matter, and the removal of this organic matter by filtration unquestionably is one of the chief causes, if not indeed the leading, of increased corrosion of metals, and a contributing factor of major importance in the causation of red water troubles. Any kind of a filter which removes this organic matter, whether or not aluminum sulphate is used with it, will yield an effluent which may be criticized on this score, for this very organic matter gathers on metal surfaces and thus forms a protective coating. There are experiences on record at variance with this viewpoint, however. The Charleston, S. C., water, drawn from a swampy watershed, was highly corrosive before filtration, according to Mr. J. W. Ledoux.* After rapid sand filtration, whereby most of the organic matter was removed, the corrosive effect was reduced to a minimum.

Organic acids in waters of this character may play some part in metal corrosion, but how far the acid character of such waters is due to carbonic acid, and how far to the but indifferently understood group of complex organic compounds, is by no means plain.

In a discussion of red water troubles one necessarily is confronted with an almost uninterrupted chain of conflicting evidence.

* *Engineering Record*, Vol. 60, p. 701.

It is probable, however, that a prime contributing factor is the lack of care with which metals are selected in building a water distributing system, and lack of attention given to artificial protective coatings. This must be so, else there would not be the common occurrence of red water on one street and none on another; in one house and not in the next. Weston (*loc. cit.*) has well said:

"If a water contain dissolved salts, even though alkaline, homogeneous metals should be used in contact with it. The insides of meters, valves, and pipes, wherever possible, should be of such a composition that electric currents will not be generated."

So far as affording a fulcrum on which to force an argument against rapid sand filters, or filters of the slow sand type where coagulants are often used, the evidence is weak and unreliable that red water troubles are due to the use of aluminum sulphate as a coagulant. The waters most liable to attack metals are pure waters containing large amounts of carbonic acid and oxygen. Filtered waters are pure waters and not infrequently contain high amounts of free carbonic acid as discharged from the filters. Aëration will remove this for the most part, and in the design of filter plants for the treatment of colored waters drawn from swampy watersheds particular attention should always be given to this feature,—far more attention, in fact, than has been devoted to it in the past.

Local Manufacture of Aluminum Sulphate.

Until quite recently, water purification works were obliged to depend on the open market for their alum. Within the last two years a process has been perfected whereby filter alum can be made readily and cheaply by the individual consumer. This is known as the Hoover Process, and was worked out by Charles P. Hoover, chemist in charge of the water purification plant at Columbus, Ohio, and on September 5, 1916, United States Patent No. 1,197,123, covering the process, was issued to Mr. Hoover.

The process itself is very simple. The raw materials are commercial sulphuric acid and low-grade bauxite ore. To make alum, two parts by weight of acid and one part of pulverized bauxite are brought together and thoroughly mixed. The mixture is

then discharged into a shallow pan or box. The reactions which ensue take place naturally, the water of crystallization is driven off and the cake hardens. It is removed from the box in lumps, and these lumps are thereafter used in preparing coagulant solutions in the same manner as when the ordinary market alum is being used.

For a plant capable of turning out a ton of alum per day, a space about 15 ft. by 25 ft. by 10 ft. high is required. Storage space for acid and bauxite is needed. No artificial heat is required at any stage of the process, and no labor other than to proportion the raw materials, supervise their mixture, discharge the mixture into the crystallizing boxes, and later remove the hardened cake. Mixing may be made easier by utilizing a small motor. About ten minutes is required to get a satisfactory mix. The simplicity of the whole procedure may be gathered from the mere statement that to make alum by the Hoover process one needs but to mix thoroughly two parts of sulphuric acid and one part of pulverized bauxite in a bucket and allow it to stand. A few hours later a cake of alum is found at the bottom of the bucket.

The alum produced by the Hoover process is a basic aluminum sulphate which is even more effective per unit of weight than the ordinary commercial aluminum sulphate purchased in the open market.

When the use of alum for water purification purposes began to spread, some thirty odd years ago, the users first turned to potash alum and later to aluminum sulphate. These chemicals had heretofore been used in paper making and other industries where a particularly pure article was required. The water filtration man immediately jumped to the conclusion that he needed just as pure a product, and was satisfied to pay a high price for a refined alum which actually, for his purpose, had had removed from it in the process of preparation a substantial amount of the active coagulating constituents.

Mr. Hoover's process does not include the filtration of the liquid chemical before crystallization, consequently none of the aluminum sulphate and basic iron and aluminum is thus lost as it is in the market alum. In the ordinary alum sludge, removed with the insoluble matter by such filtration, there is contained

some 3 to 4 per cent. of available alumina. This is retained in the Hoover alum, and lost in the regular market alum.

Hoover alum, not being filtered, contains from 7 to 10 per cent. of finely divided, insoluble, suspended matter. This suspended matter, instead of proving a nuisance, by virtue of its very fine state of subdivision serves as a nucleus around which the gathering floc can form. Actual experiments with Hoover alum and several well-known brands of regular market alum, viewed by disinterested parties, showed that, unit for unit of weight, the Hoover alum possessed the greatest coagulating powers.

But little can be said at this time about the cost of making alum by the Hoover process, since the acid market is in such an uncertain state. Roughly speaking, however, 60-degree Beaume sulphuric acid may be bought at this date for about $20 per ton, f. o. b. point of manufacture. Pulverized bauxite costs about $15 per ton, f. o. b. Bauxite, Ark. For raw materials to make a ton of 17 per cent. aluminum sulphate the cost would therefore be about $19 plus freight. In New England, the total cost of raw materials for a ton of alum would be about $25. Labor, repairs, and other incidental charges would add about $2 or less, so that at present the total cost per ton of manufacturing alum by this process would be around $27. Regular market alum containing 17 per cent. available alumina is now quoted at about $40 per ton, f. o. b. point of manufacture, and the prospects are that it will shortly go to $60 per ton.

Cities now using the Hoover process are Springfield, Mass.; Trenton, N. J.; Cumberland, Md.; Columbus, Ohio; Omaha, Neb.; and Montreal, Quebec, and a plant for making 1 500 tons of alum annually is now being built at Little Falls, N. J., by the Montclair Water Company. A good illustrated review of the experience with this process by the various filter plant superintendents in the above-mentioned cities is contained in *Engineering News*, Vol. 77, Nos. 1 and 2, Jan. 4, 11, 1917, under the caption, "Five Water-Works Make Alum."

Sterilization.

Not much need be said about water sterilization, for so much has been written regarding it in recent years that its advantages

in practically all water purification problems are well understood. Even though the continuous use of sterilizing agents in water purification began less than nine years ago, the practice has spread until, in practically all up-to-date water purification plants in this country, sterilization is an integral part of the system. Hypochlorite of lime has been supplanted in many places by chlorine gas, and sterilization by the ultraviolet ray process has been adopted in quite a number of places, the most recent relatively large installation being that at the Henderson, Ky., water works. During a somewhat protracted and carefully conducted test of that plant in March and April of this year, when about 3 000 000 gal. of water were being treated daily, after passing five lamps the filtered water contained on an average less than one bacterium of any kind, and bacteria of objectionable types were uniformly and thoroughly killed at all times.

Hypochlorite of lime solutions are not so easy to handle as chlorine gas, but continue to give good results. Chlorine gas application also requires attention, since the orifices become clogged at times with foreign matters. In the ultraviolet ray process the lamps must be watched and the current consumption kept under observation. None of these sterilizing processes is entirely automatic in its action, and all are subject to human control if consistently good results are to be obtained.

Both hypochlorite of lime and chlorine gas are unsuccessful in the complete destruction of spore-forming bacteria. For example, in Jersey City this year, during an intensive study of the character of the water supply of that city, when hypochlorite was being added to the water in quantities ranging from 0.63 to 0.91 part per million available chlorine (the upper amount being all the water could stand without producing in the water an objectionable taste of the chemical), the presumptive B. coli record of the water delivered in Jersey City was such as to pass the United States Treasury Department limit of two B. coli per 100 cc. only on ten days in the entire period of the investigation covering the months of March, April, and May. This unsatisfactory B. coli record, as proved by confirmatory tests, was caused by the presence in the water of B. welchii. These organisms, themselves of fecal origin and an index of fecal pollution, form spores which

could not be eliminated by chlorination applied within the limits possible without imparting to the water objectionable tastes and odors of the chemical. Tests which the author has made with the ultraviolet ray process showed that spore-forming bacteria are killed by it with comparative ease. Even the hardy paramæcia are killed in water by a few seconds' exposure to ultraviolet rays.

Comparing the relative merits of chlorination and the ultraviolet ray process of water sterilization, and eliminating questions of cost, it may be said that if a perfect sterilizing score is to be recorded, the water to be sterilized must be free of suspended matter. Unfiltered waters containing suspended matters, particularly where such matters are organic in character, may be sterilized with a fair degree of success by either chlorination or the ultraviolet ray process; but these suspended particles serve as admirable hiding places for bacteria, and embedded in such particles disease bacteria will remain unkilled, to pass on to the ultimate consumer. Entirely satisfactory results are obtained only when waters are filtered and freed of their suspended matters prior to sterilization.

The ultraviolet ray process possesses two advantages over chlorination. In sterilization by chlorination the chemical or gas is customarily added at a single point. In the ultraviolet ray process the water is made to pass by a succession of lamps. If the first lamp does not destroy all of the objectionable bacteria, that work is left to succeeding lamps until the desired result has been obtained. With chlorination there is a limit which one may not exceed as regards the size of the dose without imparting to the water offensive tastes and odors of the chemical. With the ultraviolet ray process, overtreatment cannot impart offensive tastes and odors to water, since nothing enters it but the invisible ultraviolet rays.

Pressure Filters.

Pressure filters of the rapid sand type are now operating on municipal supplies in this country in 140 places with a present total population estimated at 1 946 000. The combined capacity of these 140 plants is 257 200 000 gal. daily. The individual

plants range in size from 100 000 gal. daily up to the 21 000 000-gal. plant at Atlanta, Ga.

Pressure filter plants, therefore, constitute 20.5 per cent. of the total number of municipal rapid sand filter plants in the United States, 10.8 per cent. of the total filtering capacity, and serve 10.6 per cent. of the total population served.

It is not considered necessary in this paper to discuss at length the relative advantages of gravity and pressure filters. A recent article on the subject,* and the discussions accompanying it, cover the matter in a quite thorough fashion.

The first rapid sand filters installed in this country for the purification of municipal water supplies were of the pressure type, and in the growth of the filtration art such shortcomings as these earliest filters possessed have been handed down and accepted by some as inherent defects in the process. The first pressure filter plants were without adequate facilities for proportional chemical application, and rate control was a matter to be governed by the demand for water. The same history can be recorded for the gravity filter, but the latter is capable of greater elasticity in individual design, and consequently it was favored in the development of new ideas.

The pressure filter was, and still largely is, of stereotyped design. It was considered by many to be automatic in its action and to need no attention or control other than cleaning when it became clogged and failed to yield enough water. The model pressure filter of to-day can be fitted with rate controllers and devices for accurately proportioning the dose of coagulant. Everything that can advantageously be built into a gravity filter system is equally applicable in a pressure filter system.

The pressure filter is particularly adapted to water problems where double pumping is an important item of expense, since with this type of filter one pumping may be avoided. Along the general line of filter-operating economy it is significant that the pressure filter is looked upon with considerable favor by private interests. Of all the pressure filter plants operating on municipal supplies in this country, over one third are owned by private

* "Pressure Filters," by Harold C. Stevens, *Journal of the American Water Works Association*, Vol. 3, Nos. 2 and 3, 1916.

companies. Such companies certainly operate their properties as economically as possible, the first thought of the business man naturally being to furnish satisfactory service at the lowest possible cost. Such operators of pressure filter plants evidently are able to secure good service for less money than would be possible with gravity filters.

Since water sterilization gained an accredited standing, the requirements of water filters, *per se*, have been altered materially. With the realization that cheap and efficient means had been found whereby dangerous bacteria in water could be readily killed, the necessity of relying upon the filter itself for high efficiency in this respect passed away. The filter is still needed to remove color and turbidity, but sterilization of the physically satisfactory water may be relied upon to insure the performance of the really consequential phase of the bacterial side of the purification process.

To those who perhaps would prefer to use pressure filters, this point is one of much significance. Probably not a few places have adopted gravity filters because they feared the pressure filter would not give the required high bacterial efficiency. When this doubt now arises it is answered in a satisfactory manner by sterilization. A properly equipped pressure filter plant, efficiently operated, will yield just as good appearing an effluent as a gravity filter, and any dangerous bacteria which may escape from this or any other filter can be killed by sterilization.

Discussion.

Mr. L. M. Hastings.* This subject is of vital interest to every one who has charge of water works, and especially those who have surface water supplies. Nearly all of us have suffered more or less from color and taste of the water, and, as Mr. Johnson and others have said, the only remedy seems to be either filtration or sterilization. Now, when you introduce alum or chlorine, there is always a feeling in the popular mind that there is a taste left in the water unless the operation is very carefully conducted. I suppose it would be very difficult to satisfy the

* City Engineer, Cambridge, Mass.

public generally that there is not some taste remaining in treated water. I should like to ask Mr. Johnson whether there was any special method of treating, other than what he mentioned of using care to avoid over-dosing, so that the peculiar taste of the chemical might not remain. I suppose, after one case of over-dosing, the people who got that taste will never forget it and will always say, "Well, your filtered water is all right, but it tastes."

Now, after we have treated our water and got it pure and sterile at the filters, what is its condition after passing through dirty and foul pipe? I should like to ask Mr. Johnson whether there are any data showing how necessary it is, how frequently — where chemically treated water is used — it has been found necessary to wash out the distribution pipes. Any one can see that, no matter how pure and clear the water is, by passing it through 100, 150, or 200 miles of foul, contaminated pipe, you are likely to get an unsatisfactory result.

The next question relates to wash-water. Take a case of a system that is pretty near to its limit of capacity. The reduction of the available supply by abstracting 2 to 7 or 8 per cent. of the water for washing purposes and then running that away to the sewers seems an important matter. And it seems as though it would be practicable to recover that water, or a considerable proportion of it. After it had been used once, if you could then wash the water again and use it there would be a great saving. Whether that is practicable or not I don't know.

Mr. Johnson. There is not any question that the bad name that alum got in the early years of water filtration was due to the use of the old-fashioned alum pot in connection with the pressure filter. In those days there was very little attention given to the proportion of the coagulating chemicals with the raw water; but in the past twenty years precise devices have been invented and put into practical service which render it easy to get an exact adjustment of the coagulating chemicals at all times. There is no excuse whatever in any plant operated by an intelligent filter operator of ever getting an overdose of alum. We all know that the dose of chemical is adjusted according to the physical imperfections of the water. If the natural alkaline content of the water is not sufficiently great to thoroughly decompose all of the

coagulating chemicals, — that is, to effect adequate coagulation, — then the practice is to apply artificial alkalies, like soda ash or lime, to make up this deficiency and prevent any undecomposed alum passing into the plant. There is not any question either that in a great many cases the people think they can taste alum in the water long before the alum is ever applied to it. That has been learned in a number of cases. You don't have to have the alum in the water so long as they can taste it. But in these days we don't give any concern at all to the possibility of undecomposed alum going through the filter plant. That is under such good control now that it is no longer considered to be even a possibility with efficient operation. But it is like other things, it is subject to human control, and sometimes of course it might fail, although it never has in my experience.

Now, in reference to the cleaning of mains following the construction of a filter plant, I think the usual custom is to give them a good thorough blowing-out, and that is about all. Of course, if there has been an epidemic just prior to the installation of the filter plant, it is not unusual to treat the water in the mains with a heavy dose of germicide. I think one of the first cases on record was at Lincoln, England, where they had an epidemic of typhoid fever, which was followed by an intensive sterilization of the water in the mains. It is rather a peculiar thing in this connection that when a filter plant is turned into service its effect is immediately noted even though there may not be any particular effort made to clean out the pipes. I have one particular case in mind, — that at Norfolk, Va., where some eighteen or more years ago that plan was put into operation. The newspapers the next morning came out with large headlines to the effect that it was easily seen that the water had been given a bath. It changed from a dark amber color to a clear, colorless water. And there was no special effort made to flush out the pipes. In time the system will probably clean itself.

As to the utilization of wash water, I know Mr. Hastings refers to his own problem in Cambridge. The possibility was considered very carefully there of conserving the wash water by discharging that wash water into a storage tank where it would be allowed to settle and then be pumped back into the settling basin;

or to catch it in this basin and pump it back without sedimentation and thereby conserve the entire water that was used for washing the filters — simply use it over and over again. There seems to be no objection to that.

Mr. R. S. Weston. I might say for Mr. Hastings' information that the conservation of wash water has been practiced in one case I know of, where the wash water was discharged into the pond and the clarified water pumped back into the basin. At Baltimore they provide a large pond for the clarification of the wash water, and that water is surprisingly good. It can be used over again much better than the raw water.

Mr. W. C. Hawley.* When our new filter plant was built, the saving of the wash water was considered, and they built a small tank into which the wash water was discharged, and after five or six hours' sedimentation the water is pumped back into the settling basin. The analysis of that water showed that the settled water is better water than the raw water coming to the basin. Our total loss of wash water is only about one tenth of one per cent. We are pumping our water against a head of about 630 feet, and that of course makes it desirable to conserve that water.

Mr. R. E. Wise. I would like to ask Mr. Johnson what color the public is satisfied with in the filtered water, — that is, whether they would be satisfied with 15 or 20, or what is the general rule?

Mr. Johnson. I believe that water should not contain more than 10 parts color, although you can get by with 15 parts. Water with more than 10 parts color to the million will show up badly in a bath tub.

Mr. William Jay Willson. I would like to ask Mr. Johnson if he has any data which will show what per cent. of water works with filter plants produce water with a color of less than 12 parts to the million.

Mr. Johnson. I think it can be said almost without reservation that in the vast majority of filter plants either of the slow sand or the rapid sand type, wherein a coagulating chemical is used, the average color of the effluent will be less than 10, although there are cases that I know of — Springfield is one of them —

* Wilkinsburg, Pa.

where it is not considered necessary to get down to that fine point.

Mr. Elbert E. Lochridge. On the question of clearing out the system when filtered water is applied, I would like to say that in Springfield we did do this. The object of this clearing, however, was a little different. Bringing in the new supply from the west, while the old came in from the east, changed the direction of flow through a great many of the pipes, and for the purpose of removing material, or the rust or sediment which had collected in the pipes, each street was figured to get a 9-foot velocity, and hydrants or other openings sufficient for this were opened. This 9-foot velocity in the pipe will take almost everything there is in the pipe out. And we have found that that has been beneficial. On the other hand, it is not necessary. Your improvement in water from filtration will come at once, and it should be remembered that the sediment which forms in pipes is something which the condition in the pipes allows to settle there or to form there, and there is not a tendency, unless that condition is changed, to again pick that material up in the normal use of those pipes.

Taking Mr. Johnson's point of color — I am not inclined to quarrel with him as to what is the proper color, but he has referred to the fact that we consider 15 or 17 or 20 sufficient in Springfield. I think this is a good deal a matter of the condition of the individual case. If you are able to get a water with reasonable treatment, which, with the small alkalinity which you have can always be obtained at the point at which it would be thoroughly stable, and if that water is satisfactory on the table, always clear, you have reached one of the main points which govern what that color should be. I find that a city which is perfectly satisfied with a color of 30 or 40 when it is not filtered, after they have had filtered water for awhile they are not satisfied with 25. If you give them 15 for awhile, they will want 15; they will not be satisfied with 20. But I have not been able to determine that there has been any appreciable demand for a color of 10 if you are giving them 15. I suppose if we educate them farther they will demand water of 5, and after that we will have to go farther yet. But a water which does not show color in a glass on the table does not call attention by its color to its presence, and

that is one of the main features for determining the color, which should be under 20. And I believe there are thoroughly satisfactory waters with colors above 20.

Mr. J. S. Dunwoody. The subject of Mr. Johnson's paper is of vital importance to engineers and water-works superintendents, especially if they are anticipating the construction of filter plants. And as Mr. Johnson has mentioned the Erie case and given a description of the false bottom strainer system, I might add a few words, after a few years of operation of this Erie plant, about the results we have obtained there in our false bottom strainer system. The plant completed its third year of operation the 1st of July of this year. At that time we had not had one bit of trouble of any kind in regard to our strainer system or our false bottom system. Of course, the life of this false bottom we are not able to state inside of three years, although these false bottoms have been carefully inspected every year, and while they are covered with barnacles, there is no indication that these barnacles are having a serious effect. The strainer system has never given any indication of plugging, and we have had no trouble with the water. We have a very even bed throughout the entire area, using a wash of about 10 gallons per square foot per minute. While the plant was designed for a heavier wash than that, we found we got a very heavy wash at 10 and use the 10-gallon wash about eleven months out of the twelve. During a period of two weeks in the spring and fall we increase the wash slightly. This system of strainer false bottoms in Erie has been a very great success and has given no trouble at all.

MECHANICAL FILTER BOTTOMS AND STRAINER SYSTEMS.

BY ROBERT SPURR WESTON, C.E., BOSTON, MASS.

[*Read September 12, 1917.*]

It is unnecessary to recall to your minds that the strainer system of the mechanical filter, unlike that of a sand filter, serves two purposes, namely, it must collect filtered water from the sand and must serve as a distributing medium for the wash water used for washing. Unfortunately, the velocity during washing may be more than five times the velocity during filtration, and this, of course, introduces great difficulties in design; for it is essential that the rate of filtration be uniform throughout the whole sand layer, and that the wash water be distributed as uniformly as practicable over the whole filter area so that it may rise as a plane or sheet for the purpose of separating the accumulated coagulant and fine suspended matter without at the same time causing any considerable loss of sand.

As many will remember, the simplest and perhaps the earliest form of strainer system was a perforated metal plate. This is used no longer except for small filters. The next step in advance was to screw strainers or "sand valves" directly into the perforated metal plate. There have been many kinds of strainers. The early ones were made of fine, perforated metal or wire cloth supported by a suitable brass casting. Later strainers were provided with drilled or punched holes or sawn slots. Most of the openings in these earlier strainers had a diameter or width of less than 0.1 mm.

In the earlier filters the sand rested directly upon the strainers, with the result that the fine perforations clogged quickly, making extensive and frequent repairs necessary. The remedy was to enlarge the perforations in the strainer and to place above the same a layer of graded gravel about six inches in thickness. This prevented the sand from reaching the strainer, and clogging did

not occur. About the same time it was found that in the space below the false bottom the velocities of flow were so low that sand and coagulated matter accumulated, thereby furnishing a pabulum for the growth of bacteria. Therefore, notwithstanding the fact that the false-bottom type of filter was ideal for the distribution of wash water, a pipe manifold was substituted for the false bottom in order to maintain higher velocities in the under-drains.

The early filters were circular, and were equipped with revolving rakes to agitate the sand during washing. Wash-water velocities of less than one vertical foot per minute were used. Later (about 1893) the air agitation system was introduced by the Continental Filter Company, thus permitting rectangular construction and concrete filters. The rakes were abandoned soon after.

The Little Falls plant, put in operation in 1902, typifies the best practice of the time. The strainer consisted of a perforated metal cap attached to a threaded fitting from which a small tube depended. In one side of this tube, near the fitting, was a small hole through which air passed for the purpose of agitating the sand layer. The dependent tube formed a trap so that the strainer could be used for both air agitation and wash-water distribution. This strainer system has been fairly successful, although hard spots occur in the filter from time to time, and special cleanings of the filtering material have to be made. Low wash-water velocities were employed, and air agitation was necessary.

The next large filter plant to be built was the one at Cincinnati, which was put in operation in 1907. This marked a new departure in that air agitation was done away with and a wash-water velocity of 22 vertical inches per minute was found to be necessary for the perfect cleansing of the sand. The strainer system consisted of perforated plates covering concrete channels located at the bottom of trough-like depressions running lengthwise of the filter. This bottom is illustrated in Flinn's "Handbook" and described in Ellms's new book on "Water Purification." The trough-like depressions were filled with gravel, and, to prevent its displacement during washing, wire-cloth screens were bolted to the tops of the troughs. These retained the gravel effectively and prevented the passage of sand into the filters, but it has been found

that they corrode rapidly in certain waters, notably at Cincinnati, and recently they have been removed and the necessity for their use avoided by increasing the depth of gravel above the strainers to 14 inches.

The Cincinnati type of filter bottom, while efficient, is quite expensive, and the next step was to secure the same results for a lower cost. The strainer system used at Harrisburg, Pa., consisted of a pipe manifold on the under side of which holes were drilled. The pipes composing the manifold were $1\frac{1}{4}$ in. in diameter, laid 6 in. apart, and drilled with $\frac{7}{32}$-in. holes spaced 3 in. center to center. In this filter, air was used for agitation. Somewhat later, filter bottoms of the Harrisburg type, in which the use of air was omitted, the velocity of wash water increased, and the gravel layer deepened to 14 in. or more, were used, probably first by Philip Burgess, C.E., of Columbus, Ohio. A similar form used at Toledo and Youngstown, Ohio, both of which plants were built by the Norwood Engineering Company, consists of the ordinary pipe manifold into which star-shaped strainers of the Norwood type were screwed. The Norwood Engineering Company has always believed in air agitation, and all of their filters are constructed with this end in view. Nevertheless, there is no reason why this type of filter bottom may not be used without air agitation, provided the strainer openings are enlarged, the gravel layer deepened, and the wash-water velocities increased to the optimum for the sand employed.

The next improvement was the so-called Wheeler filter bottom, consisting of inverted pyramids filled with spheres covered with a layer of gravel 6 to 8 in. in thickness. A series of channels corresponding to the pipe manifold communicate with the orifices of the respective pyramids. The advantages claimed for the Wheeler filter bottom are the better distribution of wash water secured by uniform material uniformly placed; the absence of metal in contact with the water, thereby increasing the life of the bottom; and its lower cost.

Probably the newest and yet the oldest type of filter bottom is that exemplified at Alliance, Ohio; Muncie, Ind.; Warren, Pa.; Shreveport, La., and Erie, Pa. This consists of a false metal bottom into which brass strainer nozzles are screwed, spaced

6 in. apart. It is the false bottom of the earlier design, but the strainers with fine openings have been replaced with those having large openings. The gravel layer has been deepened, and wash water of high velocity is used. False bottoms of concrete have been suggested and have been built at Miraflores, C. Z., and at East Liverpool, Ohio; but the difficulties in the way of the successful design of a tight structure of this kind have caused conservative engineers to avoid it. Furthermore, it is believed that the space beneath the false bottom is a disadvantage, as mentioned above.

Mr. William Wheeler is now building for the Winchester Water Works Company (Ky.) a filter bottom having the usual pyramids and balls, but instead of channels beneath the pyramids there is a rectangular space like the filters mentioned above.

The most generally satisfactory strainer systems are the following:

1. Manifolds, strainers and a 14-in. layer of gravel.
2. The Harrisburg system of perforated pipes with a 14-in. layer of gravel.
3. Troughs having strainers at their bottoms, with a 14-in. layer of gravel.
4. The Wheeler filter bottom with 8 in. of gravel.

All of these systems should be designed to wash the sand layer without the use of air. Each system has its advantages and disadvantages, but the excessive cost of system No. 3 makes its use inadvisable. There are, therefore, three systems left. Of these, system No. 2 — the Harrisburg system — is the simplest. It, however, consists largely of metal, all of which is exposed, and at the present prices is probably more expensive than the Wheeler filter bottom. System No. 1, like that installed by most of the filter companies, possessed the advantage over system No. 2, the Harrisburg system, of having the outsides of the pipes protected by concrete. The strainers, however, are exposed and must be constructed of bronze, which at present prices makes the installation costly, probably the highest of the three. The insides of the pipes are likewise exposed.

In either of the above systems there exist " dead " spaces on the floor of the filter between the openings, where the wash water

does not readily reach. This difficulty is overcome in systems Nos. 3 and 4, of which No. 4, the Wheeler filter bottom, is the cheaper. The advantages of the Wheeler filter bottom consist in the absence of metal (with the exception of the short brass tube at the apex of the pyramid); the nearly perfect distribution of the wash water secured by the "ball nozzle" effect of the balls; the lower cost, and the thinner gravel layer. The writer of these notes believes that the Wheeler filter bottom is best when placed above channels rather than built as a false bottom of the filter, although to construct the latter is perfectly feasible.

Considerable difficulty has been experienced with the Wheeler filter bottom at Akron because of sand passing through the gravel around the walls of the filter, particularly at the corners. The writer has investigated this filter, and found that there was a ledge 1 in. wide left around the walls of the filter, and furthermore, the gravel layer was only 6 in. in depth. It was very difficult for the workmen to spread 1.5 in. layers of gravel evenly in the large units (2 000 000 gal. daily); consequently the sand had passed through the gravel in certain places until it rested on the ledge around the walls of the filter. This sand remained inactive. The difficulty was overcome by increasing the thickness of the gravel layer around the walls of the filter, particularly at the corners. Less than 0.5 per cent. of the area of the filter was involved. This is a very low percentage of sand surface out of action because of lumps, hard spots, etc., and the difficulty can be readily overcome. It would probably be best in a new filter with this bottom to make the gravel layer 8 in. in thickness, — namely, 4 in. coarse gravel, 2 in. medium gravel, and 2 in. fine gravel, rather than 3 in., $1\frac{1}{2}$ in. and $1\frac{1}{2}$ in., respectively, first used. Where the filter area is small, the thicknesses of the gravel layers may be reduced to those last given.

In large filters there seems to be a tendency towards wave motion in the underdrains, which may accumulate pressure at certain points in the filter bed, particularly at the ends of the channels, and may possibly cause the rupture of the gravel layer if it be too thin. This statement of course applies equally well to the three systems under consideration. The Wheeler filter bottom is better designed to resist jet action from the strainers

than are either of the others. The effect of a large ball immediately above the orifice is absolute and unchangeable.

The discussion regarding choice of filter bottoms at present centers around the relative merits of the false bottom and the strainer or manifold type. The false bottom was used in the Miraflores (C. Z.), Erie, and other plants, but only a few plants have been so built. The fear in the minds of operators of filter plants is that they may not prove so efficient bacteriologically as a plant designed on the other plan. On the other hand, the false bottom approaches nearer the condition for successful washing, — namely, that of a series of orifices discharging from a tank, — but with underdrain channels of sufficient size, relative to the areas of the orifices discharging from them, good enough distribution may be secured for all practical purposes, and the dangers, both structural and in operation, which the false bottom presents, avoided. There should be no objection to the use of the false bottom in small filters.

Thirty years' experience, and the results of experiments by Ellms and others, indicate that the successful filter will be washed at a high velocity with water alone. This effect is best secured by a strainer system consisting of orifices, above each of which is placed a layer of graded material to prevent sand from passing out of the filter, either when filtering or washing.

The underdrain system should be designed to throttle the discharge of wash water to the orifices. The latter should be reasonably large to avoid unusual loss of head in the filter, and the underdrains should be proportioned to the orifices. The false bottom system, while cheaper, is not so reliable as the other systems, and there are more or less troublesome results from cast or wrought iron headers and manifold strainer systems, even when they are cheaper, which is rarely the case. The Wheeler bottom, with sufficient gravel, best fulfills the conditions of practice. It is, however, on account of its being a patented device, more expensive than the Harrisburg system. On the other hand, it is more durable.

Discussion.

Mr. Harold C. Stevens. Mr. Weston spoke of the necessity of avoiding considerable resistance at the entrance to the strainers, the purpose being to minimize the effect of lost head as the water passes from the entrance to the strainer system into the strainer. I suppose at the older plants there may be a loss of head of a foot, which might correspond to the difference in discharging capacity from the near strainer to the far strainer of as much as ten per cent. That would tend to permit clogging to take place first along the sides or the corners of the tanks and work gradually towards the centers. Very likely there are a great many plants where the sand bed has to be taken out and cleaned with comparative frequency, which could be improved by putting in new strainers with greater resistance and by modifying old ones to give the same resistance.

REPORT OF THE JOINT COMMITTEE ON WATER CONSUMPTION.

[*Presented September 13, 1917.*]

This committee was appointed for the purpose of securing, by coöperation with the American Water Works Association, a standard form for water consumption statistics that would be adopted by both associations. The American Water Works Association appointed the following conference committee: Edw. S. Cole, chairman; Wm. W. Brush, J. N. Chester, J. H. Dunlap, J. H. Purdy.

Joint meetings have been held, and various members of the committee have presented their views in writing. A joint report was prepared with the unanimous assent of both committees, which was presented to the American Water Works Association at its annual convention in Richmond, in May, 1917, and formally adopted.

Your committee submits, for consideration, two forms to be used in the collection and publication of water consumption statistics. These forms are described as follows:

Form "A," to be used when only water consumption statistics and those closely allied thereto are to be presented.

Form "B," to be used when incorporated in a report, based on the form adopted by the New England Water Works Association and by the American Water Works Association in 1908.

These forms are attached hereto. They have been made as simple as possible, and consistent with the presentation of information which it is believed will be useful to the water supply profession.

Your committee has been impressed by the dearth of water consumption statistics which are comparable and typical of the various sections of this country. It believes that this Association would be rendering a service that the membership generally would appreciate, if the Association should publish yearly the consump-

tion statistics of typical communities in the various sections of our country. These should be selected so that the statistics of a fully metered community would be placed in comparison with those of a city in which only a small fraction of the supply is metered. By selecting, say, from fifty to one hundred of such communities and enlisting their aid in furnishing accurate statistics, information of great and increasing importance would be made available. Each five years, beginning with the year 1920, statistics should be published, setting forth the more important water consumption figures for a much larger number of cities, selecting these so that a reasonable percentage of each size would be recorded. It is suggested that this list include all cities having a population of over 500 000, 50 per cent. of those having a population of from 250 000 to 500 000, 25 per cent. of those having a population of from 100 000 to 250 000, and 10 per cent. between each of the following limits:

50 000 to 100 000.
25 000 to 50 000.
10 000 to 25 000.
Under 10 000.

By coöperation with the American Water Works Association, the labor and expense of collecting and publishing this information can be divided between the two associations, and the information furnished to the combined membership.

Your committee makes the following recommendations:

First: That Form "A" be adopted for use where water consumption statistics only are to be recorded.

Second: That a committee on uniform annual reports be appointed, the membership to represent those interested in pumping, filtration, water consumption, distribution, services, meters, and financial questions; that the American Water Works Association be requested to appoint a similar committee; that these committees, if possible, agree on a statistical form which will cover the entire water-works field; that the committee of this Association report at the next annual meeting the form recommended; and that this committee also report to what extent the Association should collect and report statistics, giving the names of the com-

munities from which such statistics should be regularly obtained and published.

Third: That your present committee should be finally discharged.

Respectfully submitted,

EDW. S. COLE, *Chairman.*
C. M. SAVILLE.
D. A. HEFFERNAN.
P. R. SANDERS.
E. W. KENT.

NEW YORK CITY, N. Y.
August 1, 1917.

FORM "A."

(To be used when only water consumption statistics and those closely allied thereto are to be presented.)

1. City or town . . . .
2. Year for which report is made . . . .
3. Municipal or private . . . .
4. Miles of mains . . . .
5. Range of domestic pressure . . . . Is fire pressure raised . . . .
   What is fire pressure . . . .

6. Population:	Last United States census . . . .
(*a*) Total	Estimated total population this date . . . .
(*b*) Supplied	Estimated total population supplied, using 5 per family . . . .

7. Total number of services in use . . . .
8. Total number of metered services . . . .
9. Per cent. of metered services (8 divided by 7) . . . .
10. How is the total water consumption determined:
    (*a*) By meter upon supply main. (Yes or No) . . . .
    (*b*) By plunger displacement. (Yes or No) . . . . . . Slip allowed . . . .
    (*c*) Other methods. Describe . . . .
11. Total annual water supplied for:
    (*a*) *Domestic uses* by metered services . . . .
    (*b*) *Commercial use* by metered services . . . .
    (*c*) *Industrial use* by metered services . . . .
    (*d*) *Public uses* by metered services . . . .
    (*e*) Total metered use . . . . Estimated public use unmetered . . . .
    (*f*) TOTAL ACCOUNTED FOR . . . .
    (*g*) Total annual amount of water supplied, gallons daily . . . .
    (*h*) TOTAL UNACCOUNTED FOR . . . . Per cent. total supply . . . .

12. Minimum night rate (1 A.M. — 4 A.M.) . . . .
    State how this rate is obtained . . . .
13. Maximum rate
    (*a*) Without fire . . . .
    (*b*) With fire per hour . . . . . . per day . . . . per month . . . .
14. Total metered use per capita daily . . . . What population . . . .
15. Average supply per service per day, gallons . . . .
16. Average supply per day per capita based on:
    Total population . . . .
    Population supplied . . . .
17. Estimated total daily supply obtained by manufacturing or other plants from sources other than the city supply . . . .
18. Total per capita daily use, including all supplies . . . .
19. Cost of supplying water per million gallons, figured on total operating and maintenance . . . .
20. Total cost of supplying water per million gallons, figured upon total operating and maintenance, depreciation, and interest upon the fair value of the plant . . . .
21. Revenue per million gallons . . . .

NOTE. *Commercial:* Stores, office buildings, hotels, boarding houses, and similar establishments.

Industrial: Railroads, factories, public gas and electric plants.

Public: All water for public use.

FORM "B."

(To be used when incorporated in a report, based on the form adopted by the New England Water Works Association in 1902.)

1. How is the total water consumption determined:
    (*a*) By meter upon supply main. (Yes or No) . . . .
    (*b*) By plunger displacement (Yes or No) . . . . . . Slip allowed . . . .
    (*c*) By other methods. Describe . . . .
2. Total annual water supplied for:
    (*a*) *Domestic uses* by metered services . . . .
    (*b*) *Commercial use* by metered services . . . .
    (*c*) *Industrial uses* by metered services . . . .
    (*d*) *Public uses* by metered services . . . .
    (*e*) Total metered use . . . . Estimated public use unmetered . . . .
    (*f*) TOTAL ACCOUNTED FOR . . . .
    (*g*) Total annual amount of water supplied, gallons daily . . . .
    (*h*) TOTAL UNACCOUNTED FOR . . . . Per cent. total supply . . . .
3. Minimum night rate (1 A.M. — 4 A.M.) . . . .
    State how this rate is obtained . . . .

4. Maximum rate:
   (*a*) Without fire. . . . .
   (*b*) With fire per hour. . . . . per day. . . . . per month. . . . . . .
5. Total metered use per capita daily. . . . . On what population. . . . .
6. Average supply per service per day, gallons. . . . .
7. Average supply per service per capita, based on:
   Total population. . . . .
   Population supplied. . . . .
8. Estimated total daily supply obtained by manufacturing or other plants from sources other than city supply. . . . .
9. Total per capita daily use, including all supplies. . . . .

NOTE. *Commercial:* Stores, office buildings, hotels, boarding houses, and similar establishments.

Industrial: Railroads, factories, public gas and electric plants.

Public: All water for public use.

SOME EXPERIENCES WITH A TRENCHING MACHINE.

BY GEORGE W. BATCHELDER, WATER COMMISSIONER,
WORCESTER, MASS.

[*Read September 12, 1917.*]

In 1913 it became evident that the city of Worcester had outgrown its water supply lines, and plans were accordingly made to lay additional pipes in 1914.

In preparing for the large work which was to come, the question of the most economical methods suggested the advisability of using a trenching machine. After examining several different machines, it was decided to purchase an Austin machine, which was secured at a cost of $7 000 less 5 per cent.

This machine reached the city in due season, was unloaded and driven to the scene of its first work by a demonstrator sent by the company at the expense of the city. The machine was put to digging a trench on Stafford Street for a 36-in. pipe buried in a trench approximately 6 ft. deep. It was equipped for this work with buckets 36 in. wide, the teeth on which projected 3 in. on each side, making a cut 42 in. wide.

As it was necessary to make the trench about 5 ft. wide, this was accomplished by barring down the banks of the trench in advance of the buckets, and feeding material so broken off into the machine as it operated. From two to three men were used on each side of the ditch to handle the bars and break down the banks. The capacity of the machine is so great that it will take out all the material dug in the regular way in addition to that tumbled into the ditch by the use of bars.

In digging this ditch on Stafford Street varying kinds of material were encountered; at the beginning, the soil was quite a heavy gravel containing some bowlders of considerable size; later, a fill was reached, and from the bottom of the trench the machine removed without difficulty a considerable number of flagstones approximately 3 ft. long by 18 in. in width.

Later a fine gravel, and still later a heavy gravel, was encountered, which the machine handled without difficulty.

In another part of the location the soil was largely composed of sand through which the machine plowed its way with great ease and speed; so rapidly, in fact, that it was operated for only a few hours each day, it being found that the pipe-laying organization could not keep pace with it, and it was impracticable to open too long a trench.

Thirteen thousand feet of this 36-in. pipe was laid in 1914, and the machine did the rough trenching for about 9 000 ft. The machine was then driven to Chandler Street, and put in service excavating for a 48-in. and 42-in. pipe. The extra width of trenching was handled in the same way as previously explained, and with equal satisfaction.

Later a cut of several hundred feet of trench for a sewer 12 ft. deep was made in extremely hard clay, reducing the cost of the work very materially over hand labor.

The machine can be used to the best advantage in new streets, but it can be operated without extreme difficulty in city streets by raising the boom at points where cross connections are encountered and lowering again after they are passed. It cannot be used conveniently in narrow streets except by closing them to traffic.

The best way to operate the machine is to rig it to convey the spoil to a bank on the extreme side of the street, with the pipe on the opposite side ready to be rolled over to the trench when the machine has passed.

While the city of Worcester lays many miles of water pipes each year, the problem has been to find work for the machine, and it has been rented at various times to the mutual advantage of the city and the contractors.

The machine is so well known to the members of this Association that a description of it would be superfluous, especially as it is now in service in Hartford, and an opportunity to see it in action will be available.

It has given excellent satisfaction, and in such times as these, when scarcity of labor prevails, it makes the work of pipe laying possible with a small number of men. It is seldom out

of repair, standing up under the rugged work it has to do in an excellent manner. The necessary repairs consist principally of replacing occasional broken teeth on the buckets or links for the chain.

Its capacity has not been fully determined in Worcester, because the pipe-laying organization was never large enough to keep within sight of it. It has made, under good conditions, a cut 6 ft. deep and 5 ft. wide at a rate of 18 in. a minute, or 20 ft. an hour, and has been estimated to cut a trench as rapidly as 150 men would do it.

Records show that it will deposit on the bank ordinary gravel or sand at a cost of approximately five cents per cubic yard.

The machine requires from ninety to one hundred pounds of coal per hour, two quarts of cylinder oil, one pint of machinery oil, and about two pounds of cup grease per day.

It requires two men, one operator and one fireman. There should be at least one man in the rear of the machine to look after conditions in the trench, to warn the operator of the presence of large bowlders or anything else which might interfere with the safe operation of the machine, to signal to stop before large stones are dropped on the conveyor belt, and in general to assist the operator.

More men are of course needed if the trench is to be wider than the regular width of the cutters, and to help in removing large stones after they are brought to the surface by the buckets. Records picked at random show what the machine has done on many occasions in this city; the time given in each case is the total time, which includes starting, stopping, and idle periods when hand work is being done in the trench.

June 26, 1917,	New Park Avenue,	155 ft. long,	36 in. wide,	5 ft. deep,	5 hours
June 27, 1917,	New Park Avenue,	200 ft. long,	36 in. wide,	5 ft. deep,	6 hours
July 6, 1917,	New Park Avenue,	220 ft. long,	36 in. wide,	5 ft. deep,	7 hours
July 19, 1917,	New Park Avenue,	320 ft. long,	36 in. wide,	5 ft. deep,	8 hours
July 24, 1917,	Quaker Lane,	408 ft. long,	24 in. wide,	5 ft. deep,	8 hours

A valuable machine to use in connection with the trenching machine is the back-filling machine made by the same concern which builds the trenchers. It consists of a portable gasoline

engine running by its own power and handling a scoop bucket on the end of a boom which projects from the machine across the ditch to the spoil bank.

The method followed in Worcester has been to securely bed the bottom of the pipe by hand filling and tamping; then the great bulk of the material was scooped into the trench by the machine and puddled or tamped as the work progressed.

To persons who have seen the leisurely manner in which many men back fill trenches, it is refreshing to see this back filler eat into a bank and scoop the earth back into the trench. Three men are enough to operate the back filler, — one man who rides and operates the machine and two men on the handles of the scoop.

It has been found practicable to use the trenching machine operator on the back filler, as otherwise the trencher would get too far ahead of the rest of the organization.

The purchase and use of these machines has saved the city of Worcester large sums of money and made possible the laying of long lines of pipe without prohibitive costs.

A growing city needs such machines as these, to do its work in an economical and prompt manner. With the present scarcity of labor, which is likely to continue, the necessity of labor-saving machinery such as above described is evident.

EXPERIENCES WITH UNIVERSAL CAST-IRON PIPE.

BY JOHN H. WALSH.*

[*Read September 12, 1917.*]

The Borough of the East Hartford Fire District began using the Universal pipe in 1908. We laid an 1 800-ft. line of 4-in. pipe in June, 1908, and since that time we have laid approximately 45 000 ft. of Universal pipe, sizes 4 in., 6 in., and 8 in. The first line laid has been in use now for nine years, and our records will show that we have not spent one cent on this line for repairs that were necessitated by any deficiencies in the pipe itself.

In January, 1909, the new line froze near the end, and four water-takers were cut off from water supply. We found it would be very expensive to try to thaw out the frozen part of the line, and the water-takers had wells that could be used in an emergency. So we did nothing to it until the latter part of February, when a warm spell came and relieved the frost in the ground — then the trouble began.

I was called on a Sunday morning to fix a bad leak on the line. With three men I started out in a team, taking two lengths of 4-in. Universal pipe. We drove five miles to the leak, and found that one length of pipe was cracked in the middle for a length of 18 in. We shut off the line and uncovered three lengths of pipe, or 18 ft. (the pipe is in 6-ft. lengths), and in one hour we had the water turned on again. In renewing the burst pipe we took the bolts out of two joints and loosened the bolts in the other two joints, and raised the pipe until the ends came apart. We then laid in the new pipe, dropped the joints down, tightened the bolts, and covered up the pipe. This was my first experience with Universal pipe. From that time on I have always said that this is the only pipe. It is easy to lay, easy to repair, and never gives you any trouble if properly laid and the frost doesn't catch you.

After a few hours of instruction, an ordinary laborer can lay this pipe. To lay the 4-in. pipe we need four men, — two men

* Superintendent of Water Works, East Hartford, Conn.

to get the pipe ready, and two men in the trench to lay and bolt it together. On the 6-in. and 8-in. pipe we need six men. On several extensions of the 4-in. lines we have laid 100 lengths of pipe, making 600 ft., with four men. This was accomplished in eight hours.

Several improvements have been made in the pipe during the nine years that we have been using it, such as bracing the lugs and strengthening the bell end. It can be bought in lengths from 12 in. up to 6 ft.; all kinds of bends, tees, crosses, and drop offsets, that are used in the laying of water mains, can be had for the asking. I believe our water department was the first one to call for the drop offsets, which we use in going over or under an obstacle when new lines are being laid or changes made in highways, when one must come up or go down.

Another good point I find about Universal pipe is that electrolysis will not affect it. I had trouble from burn-outs by electricity on a line we had of 4-in. bell and spigot pipe that went under a web of trolley switches and tracks. We removed the bell and spigot pipe for a distance of about 100 ft. and laid in Universal pipe. That was five years ago, and we have never had to make any repairs there since.

In our outlying farming districts, where we lay pipe to serve the farmers, we use the country roads and sometimes have to make some very short curves. I find that the Universal pipe is well adapted for this purpose. I always use, in rounding curves, a short length, say 2 ft. long, then a 6-ft. length, and 3-ft. lengths, and so on until the desired bend is accomplished. Before testing the pipe on curves, we brace the pipe against the side of the ditch with flat stones about 6 ft. apart. These braces we leave in permanently. The reason for bracing the pipe in this manner on curves is for safety when testing the pipe. Wherever we lay pipe, whether on short or long curves, we usually turn in the water and get the regular pressure on the pipe line; the gate is then shut off and we make a connection on the end of the line at the blow-off plug. We attach a pump and send the pressure up to one or two hundred pounds, and keep it there until every joint is thoroughly inspected. The pressure is then gradually let off, and everything is ready for the back filling.

In our soil, which is mostly sand, we do considerable tunneling if we are laying pipe in and along macadam roads. We dig up 8 ft. and leave 4 ft., and by measuring with a 6-ft. pole one can get the joints in the open ditch; in this way the 3-in. and 4-in. and 6-in. pipe can easily be laid. In crossing improved concrete or any kind of hard roads up to 25 ft. in width, we always tunnel the pipe through. We open the trench at each side of the roadway long enough to take in the 6-ft. lengths of pipe required to go across the road. The pipe is bolted up tightly together and both ends plugged and filled with water. We attach our pump and get the required pressure to test the joints. The water is then let out, a rope is passed under the street through the tunnel, a block and falls are used, and the pipe pulled through and bolted to the end of the pipe coming from the main line.

In conclusion, I wish to say that there are lots of little tricks that will save time and money that can be done with the Universal pipe that cannot be done with the bell and spigot pipe. At least, I have found it so in my experience with the Universal pipe joint. You need no lead, no calking — just ordinary laborers to do the work; and a little can of clean grease, a ratchet wrench to tighten up two bolts, and you have a water pipe joint that cannot be equaled in cast-iron pipe joints.

Discussion.

Mr. S. H. McKenzie. We have used a very little of that pipe, the first being laid in 1911. At the present time we have something like 25 000 ft., and it certainly has been good pipe. The first pipe that we laid was the line of 100-lb. pipe, and it has been in under a pressure of over 100 lb. since 1911, and we haven't spent one cent on it. When we thought of putting in Universal pipe our commissioners were a little bit skeptical in regard to it, so that for a test I put a gage on that line, something like 1 100 ft. long, and the gage held absolutely to the pressure at which the water was turned on. And we have laid perhaps 2 000 ft. and had the gage hold pressure over night.

About two years ago we laid a line of about 9 000 ft., of which 6 000 was in water. If we had used ordinary pipe on that special

extension the cost would have been prohibitory. There was a large quantity of water running. We sawed some pieces of $\frac{7}{8}$ board about 8 or 10 in. long, and put one of those in the ditch once in 10 ft., and laid our pipe on that, and then used a pump at the lower end of the ditch where we commenced to lay, which took care of all the water, and we were able to lay a whole day's work with just that one pump going, and if there had been bell-holes we would have had to have a man at every bell-hole. On one other extension we put in something like 9 000 ft., a good quantity of which was also in water, and more in sand cuts; and, taking both of those jobs which are naturally bad, we laid hundreds of feet at a figure as low as 66 cents a foot, including the cost of the pipe. That was about three years ago.

In regard to the joints, we have found that if we use an elastic paint in the joint it works out very well. I think it is better than the white lead, as it absolutely fills up any little depressions that might appear in the joints, and it also coats over the machined part of the joint, which is not covered when the pipe is pulled in, and where the pipe might be apt to rust up. When the pipes are taken apart, that coating is found intact. Sometimes the ends of the pipe are not coated. That is, the male end. And if you have that painted with this elastic paint it does away with the danger of the cast iron rusting up. I don't know that we have ever had in the thousands of feet that we have laid any split bells except once, and that was in a piece of 4-in. pipe. We laid 400 or 500 ft. to a drop-forge shop, a couple of years ago, of 8-in. pipe, and up to the present time that seems to have held tight. I didn't know but the heavy drops might have a tendency to shake the joints so that they might leak. But the only trouble that we have had in that line, so far, was in one joint, and that was very easily repaired.

One thing that is important in using the Universal pipe is inspecting the pipe carefully before it goes into the ditch. See that the burr on the male end is all right before you put your pipe together, for if you don't, and it is not filed off, it will make a groove in the female end; and consequently there will be a leakage in the joint. But if you turn the water on at night and turn it off in the morning, about nine times in ten you will find the joint dry.

Mr. F. L. Fuller. I should like to ask if there is any danger of these bolts rusting out.

Mr. McKenzie. The bolts are very heavy, — $\frac{5}{8}$- and $\frac{3}{4}$-in. bolts, — and, if you have ever noticed, in taking the bolts apart, for instance, on your gates, the thread inside of the nut is as a rule intact, and it would take a long time to rust a $\frac{3}{4}$-in. bolt through.

Mr. ——— ———. Can some gentleman present answer the question whether the pipe is cast vertically or horizontally? It is quite an interesting point with me because I have had some experience with it, and the excuse that was made at the time was that the pipe was cast horizontally. I have some pipe in connection with our system that has never yet been able to stand the pressures.

Mr. Alfred D. Flinn. I am informed the pipe is cast horizontally.

Mr. ——— ———. The case I referred to, we had a pressure of 125 lb. The pipe was supposed to stand that pressure. It has never yet been able to stand up to 100. Consequently, the main is lying idle, never has been put in service.

THE RESULTS OF THE USE OF METERS IN THE METROPOLITAN WATER DISTRICT, BOSTON.

BY SAMUEL E. KILLAM, SUPERINTENDENT PIPE LINES AND RESERVOIRS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read September 13, 1917.*]

It is a matter of history that the city of Boston first introduced service meters as early as 1852, as a means of checking waste. At this early date, four years after municipal water had first been introduced, waste of water became a source of anxiety to the Cochituate Water Board, and the following is taken from a report of that year: "The quantity that is used and wasted is more than double what was anticipated to be sufficient for our present population." The consumption was 8 125 800 gal., equivalent to 55 gal. per capita.

The first meters installed were known as the Huse meter, but they were not very reliable, and during the next ten years the work of installing service meters was mainly experimental. In 1861 there were 104 service meters in use, most of which had been applied to the leading hotels. The use of meters was extended year by year until in 1871 there were 1 091 meters in service. Then came a change in policy, and during the next nineteen years only six meters were installed, but in the meantime the new Sudbury River works had been completed, which promised an "inexhaustible" supply.

The quantity of water delivered to the distribution system continued to increase, and in 1879 the consumption on the high-service district, which was almost entirely for domestic use, was at the rate of 110 gal. per capita per day during the day hours and 72 gal. per capita per day during the night hours, from 11.00 P.M. until 4.00 A.M.

In the Charlestown district of Boston, in 1881, an experiment was made by using the Deacon meters to detect waste, and the per capita consumption was reduced from 58.5 gal. per day to

37.7, but the subject of waste was not taken up in earnest until July, 1883, when a systematic plan of inspection and of observation by operating the waste detector meters by districts was inaugurated under the personal supervision of the late Dexter Brackett.

In addition to the Deacon waste observations, a house-to-house inspection was made, which resulted in the issuance during the first four months of over 6 000 notices to stop the waste of water from house fixtures. The consumption in some districts at this time was reduced over 35 per cent. Much waste of water was prevented by the inspection of house plumbing, and, aided by the use of Deacon meters, the consumption was reduced from 91.5 gal. in 1883 to 68 gal. per capita in 1884.

The inspection was continued with decreasing diligence for about ten years, but the checking of waste was not permanent, and the consumption of water continued to increase as in former years.

In the early nineties it became apparent that the city of Boston had nearly reached the capacity of its sources of water supply, and there were several nearby cities and towns whose sources of supply were being investigated as to quantity and quality.

By an act of the General Court approved June 9, 1893, the State Board of Health was directed to investigate the subject of a future supply for the Boston Metropolitan District, and in February, 1895, a report was made recommending the taking of the waters of the south branch of the Nashua River at a point in the town of Clinton, the works so constructed to be utilized in conjunction with the sources then in use by the city of Boston.

The Metropolitan Water Act was approved June 5, 1895, which provided for a board of three commissioners to construct, operate, and maintain a system of water works substantially as recommended by the State Board of Health. The act further provided that a city or town, any part of which was within a radius of ten miles of the State House, should, upon payment of such sums as should be determined by the board, be admitted into the district. Subsequent legislation combined the Metropolitan Water Board and the Metropolitan Sewerage Commission into one commission known as the Metropolitan Water and

Sewerage Board, consisting of three members appointed by the governor. The board at present is made up as follows: Henry P. Walcott, M.D., chairman; Edward A. McLaughlin, and Thomas E. Dwyer; with William E. Foss as chief engineer of water works.

The Metropolitan Water District at present is made up of the following cities and towns: Arlington, Belmont, Boston, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Milton, Nahant, Newton, Quincy, Revere, Somerville, Stoneham, Swampscott, Watertown, and Winthrop. The town of Swampscott was admitted under a special act of the legislature, it being outside of the ten-mile limit prescribed in the act. The city of Newton, which is a part of the district, is still supplied from its own local source.

On January 1, 1898, the works were so far completed that formal possession was taken of the collecting works of the city of Boston, and actual operation and maintenance commenced.

Previous to the formation of the Metropolitan Water District, nearly all the cities and towns obtained their supplies from local and different sources and maintained separate pumping units, storage reservoirs, and distribution systems. After the Metropolitan Works were put in service, eleven sources of supply were abandoned and five pumping plants operated in place of twenty.

The water is delivered to the district from the Wachusett, Sudbury, and Cochituate watersheds by gravity through aqueducts, and the low-service districts are supplied in most part without pumping. In 1916, about 45 per cent. of the entire supply was delivered by gravity directly to the distribution system, the remainder being pumped and 1.4 per cent. being raised a second time by pumping for the higher elevations in the district.

In 1902, under act of the General Court, Chapter 391 authorized the Metropolitan Water and Sewerage Board to construct works for the measurement of water supplied to the cities and towns in the Metropolitan Water District and to report the quantity supplied to each, and also whether the water was being improperly or unnecessarily used, and to make recommendations in regard to preventing waste and the manner of proportioning the annual water assessment.

Before measurements to determine the quantity and waste could be made, it was necessary to provide means for measuring the water supplied to the cities and towns.

In anticipation of the passage of the act, extended studies had been made to determine the number and size of the meters which would be required for measuring the water. The Venturi meter was adopted as the best and most suitable device to measure the large quantities required without too great a loss of head. This meter is a specially designed pipe which contains a contracted section called a throat, which causes a depression in the hydraulic gradient. At the inlet end and at the throat small holes are drilled into the tube, and service pipes which transmit the pressures are connected with the registering instrument, which may be located some distance from the tube. Since the meter tube contains no moving parts or obstructions, the wear on the interior surface is imperceptible, and a throat which was recently removed after seventeen years' continuous service was found to be in excellent condition.

There are now sixty-nine meter tubes installed in the district, varying in size from 6 in. to 60 in.

The record of flow is obtained at the register, and is due to the difference of pressure on the level of a column of mercury, which carries a float. The position of this float is thus made dependent upon the quantity of water passing through the meter, and by suitable mechanism the quantity is recorded by counter and the rate of flow recorded on charts. The pressure at the throat of the meter is often several pounds less than at the inlet end, but the loss of pressure is nearly all regained at the outlet end of the tube.

There are several types of registers. All have been found to be simple and rugged in construction and responsive to minute variations in rates of flow. There are in use in the district fifty-four Type D, five Type M, and one Type V registers.

The autographic records from the registers give information regarding unusual drafts of water, and assistance has been given local water departments by notifying them of an increase of flow caused by underground leaks.

In districts where the quantity to be measured is small, the Hersey Detector meter, Model F. M., has been used.

The total cost to January 1, 1917, of installing the meters, including meter registers and appurtenances, was $94 364. The total cost for charts and repairs to meter registers since their installation in 1903 averaged about $3.50 per meter register per year.

Two men are required to devote their entire time to the reading and adjustment of the meter registers, and keeping the registers and steel tanks in which they are located in good condition. The meters are read twice each week, requiring the equivalent of eight days for one man.

A report* on the measurement, consumption, and waste of water supplied to the Metropolitan Water District, with recommendations, was made by the Metropolitan Water and Sewerage Board to the General Court in February, 1904, which resulted in the passage of an act providing that the water assessment for each municipality supplied by the Metropolitan Works be based on the valuation and consumption after the year 1905, in the ratio of one-third valuation to two-thirds consumption of water. Following as it did the investigation of the leakage in the district, made by the Metropolitan Water and Sewerage Board in the years 1903 and 1904, it is fair to assume that the act levying a part of the water assessment on consumption was a factor in keeping down the per capita consumption during the next few years.

In 1907 an act was passed providing that after January 1, 1908, all cities and towns which derived their source of supply from the Metropolitan Water Works should equip all new service pipes with water meters and should also equip annually with meters 5 per cent. of the services that were unmetered on December 31, 1907, and should thereafter charge each consumer in proportion to the amount of water used.

The quantity of water consumed became a very important element, and it was made an incentive, not only for the district as a whole, but for each municipality, and finally, the most important of all, each consumer, to check and to stop the unnecessary and wasteful consumption of water.

The gradual installation of more service meters in the district has reduced the average daily consumption per inhabitant from 130 gal. in 1907 to 89 gal. in 1916.

* Reprinted in JOURNAL N. E. W. W. A., Vol. 18, page 107.

The area, population, number of service pipes, meters, and miles of pipe in use in each city and town in the district, are given in the following table:

City or Town.	Area, Square Miles.	Estimated Population, July 1, 1916.	Services in Use, January 1, 1916.	Meters in Use, January 1, 1916.	Miles of Pipes, January 1, 1916.
Arlington........	5.2	15 670	2 753	2 755	45.10
Belmont.........	4.6	8 560	1 430	1 430	29.38
Boston..........	42.8	762 700	103 195	54 848	849.35
Chelsea.........	2.3	45 020	4 971	4 957	43.30
Everett.........	3.4	38 870	5 893	2 947	50.21
Lexington.......	16.0	5 680	1 156	1 063	36.32
Malden.........	4.9	50 160	8 055	7 696	90.18
Medford........	7.1	32 080	6 043	5 846	67.19
Melrose.........	5.1	17 260	4 005	4 211	52.99
Milton..........	12.9	8 850	1 867	1 926	50.06
Nahant.........	1.0	1 440	730	468	22.07
Quincy..........	16.5	42 030	9 315	8 248	129.74
Revere..........	5.9	26 790	4 413	3 125	52.99
Somerville.......	4.2	89 190	13 233	9 155	95.42
Stoneham.......	6.6	7 590	1 613	1 589	26.13
Swampscott.....	3.1	7 580	1 810	1 810	21.99
Watertown......	4.1	17 280	2 798	2 622	38.20
Winthrop.......	1.6	13 470	2 903	2 829	32.23
District.........	147.3	1 190 220	176 183	117 525	1 732.85

The climatic and industrial conditions are immediate factors in considering the difference in the amount of water consumed in the various districts for different years. In Boston the quantity used for business and manufacturing is larger than in any other municipality. The traveling, or suburban, population from outside the city use the water but are not included in the census population upon which this per capita consumption is based. However, if Boston is divided into various districts, as measured by the master meters, it will be observed that there has been a decided decrease in the per capita consumption in the districts since the installation of service meters.

The per cent. of services metered and the per capita consumption per day and at night in each city and town in the district for the years 1907 and 1916 was as follows:

City or Town.	Per Cent. of Services Metered.		Consumption per Capita. Gallons per Day.			
	January 1, 1907.	January 1, 1916.	1 A.M. to 4 A.M.		Average Daily.	
			1907.	1916.	1907.	1916.
Arlington	33.6	100.0	50	28	91	59
Belmont	100.0	100.0	31	18	68	52
Boston	5.5	53.2	107	62	153	105
Chelsea	14.6	99.7	59	35	97	68
Everett	2 0	50.0	50	42	82	74
Lexington	2.1	92.0	43	37	69	69
Malden	93.6	95.5	22	28	46	49
Medford	10.5	100.0	65	22	102	46
Melrose	3.9	100.0	85	26	117	45
Milton	100.0	100.0	16	10	46	42
Nahant	17.2	64.1	50	51	130	110
Quincy	14.2	88.6	66	39	100	59
Revere	4.8	70.8	54	34	82	59
Somerville	24.6	69.2	55	34	90	69
Stoneham	1.9	98.5	55	29	91	58
Swampscott	37.8	100.0	41	28	85	59
Watertown	98.3	100.0	36	29	67	65
Winthrop	2.3	100.0	65	26	105	53
District	14.7	66.8	88	51	130	89

The following table gives the per capita consumption in gallons for several years in the various districts into which the city of Boston is divided by master meters.

District by Services.	1907.	1908.	1909.	1910.	1913.	1916.
Southern Low	148	148	139	128	126	115
Southern High	162	158	151	128	100	105
Charlestown	200	195	186	188	114	113
East Boston	130	140	117	110	58	61
Brighton	132	135	108	107	77	89
West Roxbury	130	131	112	132	92	57
Breeds Island	63	60	61	53	35	31
Total	153	153	143	130	109	105
Per Cent. of Services Metered	5.6	5.7	5.8	12.5	34.8	53.2

The southern low-service district comprises the lower area of the city proper, South Boston, Dorchester, and Brighton, in which is located the greater part of the business and manufacturing plants, railroad terminals, and electric light and power plants. All the other districts are residential, although the southern

high-service district includes several of the largest hotels and some business and manufacturing plants. In East Boston and Charlestown, considerable quantities of water are used by railroads and shipping and some by manufacturing plants.

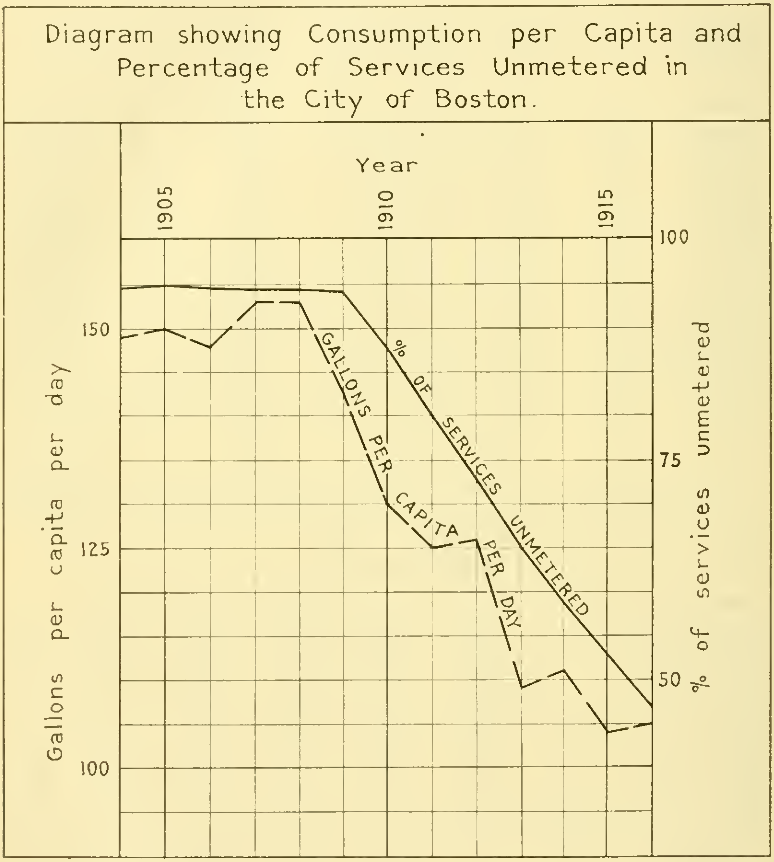


Fig. 1.

The effect of the use of service meters upon consumption of water is very graphically illustrated by the accompanying diagram, Fig. 1, showing the daily number of gallons used per capita in the city of Boston and the percentage of unmetered taps for each year, 1904 to 1916 inclusive.

There has been a gradual reduction in the quantity of water used with the increase in the use of meters.

In Melrose, which is largely residential, the reduction due to the installation of service meters was especially noticeable. The introduction of meters was begun in 1907, and on January 1, 1908, about 30 per cent. of the takers were changed from scheduled to meter rates, and at the end of the year 1908 practically all the services were metered. The records on the master meter showed a saving of 55 gal. per capita in two years, a reduction of 47 per cent.

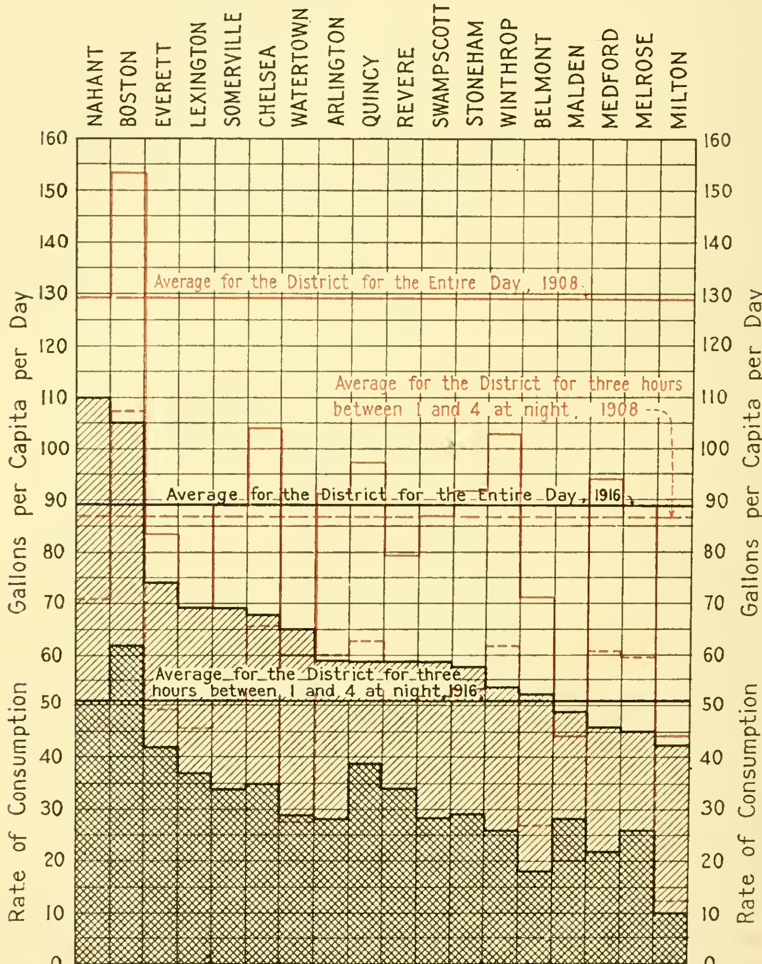
The following table gives the per capita consumption in gallons by months, per cent. of services metered in the city of Melrose, and the average temperature of the air for the years 1907, 1909, and 1916.

	Daily Consumption per Capita.			Average Temperature of Air.		
	1907.	1909.	1916.	1907.	1909.	1916.
January	113	60	43	26.1	29.4	31.6
February	125	61	43	21.6	31.6	24.4
March	116	58	44	37.5	35.2	27.8
April	109	60	43	44.0	48.6	45.6
May	111	63	46	53.7	56.2	58.3
June	120	71	46	64.7	69.4	62.0
July	122	71	45	72.6	70.9	72.6
August	131	66	49	70.0	71.0	71.0
September	116	63	49	64.5	62.7	64.2
October	115	61	47	49.1	52.6	55.0
November	113	60	45	41.7	45.3	41.7
December	115	55	44	34.9	28.4	31.5
Year	117	62	45	48.4	50.1	48.8
Per Cent. of Services Metered	3.9	100	100			

The diagram, Fig. 2, shows graphically what has been accomplished in the district during the past eight years in reducing the waste of water, and at the same time indicates that while much has been accomplished, the work is still unfinished.

The fact that between the hours of 1 and 4 A.M., when the legitimate use of water is at its minimum, water is drawn from the mains in the district at the rate of over 60 900 000 gal. in twenty-

AVERAGE RATE OF CONSUMPTION OF WATER
IN THE METROPOLITAN WATER DISTRICT
FOR THE ENTIRE DAY
AND
FOR THREE HOURS BETWEEN 1 AND 4 AT NIGHT



Percentage of Services Metered

	Nahant	Boston	Everett	Lexington	Somerville	Chelsea	Watertown	Arlington	Quincy	Revere	Swampscott	Stoneham	Winthrop	Belmont	Malden	Medford	Melrose	Milton
Dec. 31, 1908	31.0	5.8	9.6	33.1	36.6	33.9	100.0	50.1	29.9	9.7	89.2	12.8	100.0	100.0	96.3	33.1	100.0	100.0
Dec. 31, 1916	69.3	58.4	54.7	94.4	73.4	99.8	100.0	100.0	91.4	73.6	100.0	98.6	100.0	100.0	96.1	100.0	100.0	100.0

Average Rate of Consumption for Entire Day, 1916 . . . .
" " " " between 1 and 4 at night, 1916 . . .
Average Rate of Consumption for Entire Day, 1908 . . . .
" " " " between 1 and 4 at night, 1908 . -----

Fig. 2.

four hours, equivalent to 51 gal. per capita, is very strong proof that, notwithstanding the decrease in the consumption, a large amount of preventable waste is still taking place.

It will be noticed on Plate XI that notwithstanding the increase of over 335 000 in the number of people supplied, the average daily consumption was less in 1916 than it was in 1902, fourteen years ago, and the per capita consumption was the same in 1916 as in 1894.

The daily average quantity of water used in the district in 1916 was 17 808 000 gal. less than during the year 1907, and the per capita consumption has been reduced from 130 gal. to 89 gal., equivalent to over 31 per cent. This reduction in the use of water has been accomplished largely by the introduction of service meters.

The estimated safe capacity of the Cochituate, Sudbury, and Nashua supplies is 173 000 000 gal. per day. Assuming that there had been no reduction in the per capita consumption since 1907, the daily average consumption for 1916 would have been about 155 000 000 gal.

If the conditions as they existed prior to 1904 had been allowed to continue, additional sources of supply would, without doubt, have been required before the present time. It is also probable that if the act requiring the installation of service meters on all works receiving a supply from the Metropolitan Works had not been enacted, it would have been necessary to construct additional works by 1920.

It was estimated in the report of the Metropolitan Water and Sewerage Board to the Legislature of 1904 that the cost of new works required within the next twenty-five years to supply the probable demand for water if the waste was not checked would be at least $32 000 000, assuming that the district remained as constituted at that time.

The greater the quantity of water used, the more it costs in the end to furnish water to the tap. At a fixed rate the consumer is charged a certain sum and naturally is not directly interested in leaky pipes as long as no damage is caused by the water. The leaks increase in volume and the quantity of water required for legitimate use is running to waste. Wasted water means larger

mains, more pumping machinery, wasted coal and labor, and, finally, extension of works for larger supplies and an increased sewer system to care for the wasted water.

Many are willing to pay for their own and their neighbors' waste by general taxation, but are unwilling to continue to pay for their own waste when presented with a quarterly bill.

The writer believes that water meters are as much a part of a well-operated water-works system as gas or electric meters are to their respective works. Many gas companies account for 80 per cent. of gas delivered through the master meters. The master meters on the distribution system of the Metropolitan works account for practically all the water delivered to the works from the watersheds. Well-managed water works in Europe account for all but 10 per cent. of their supply. Cannot American municipalities do as well?

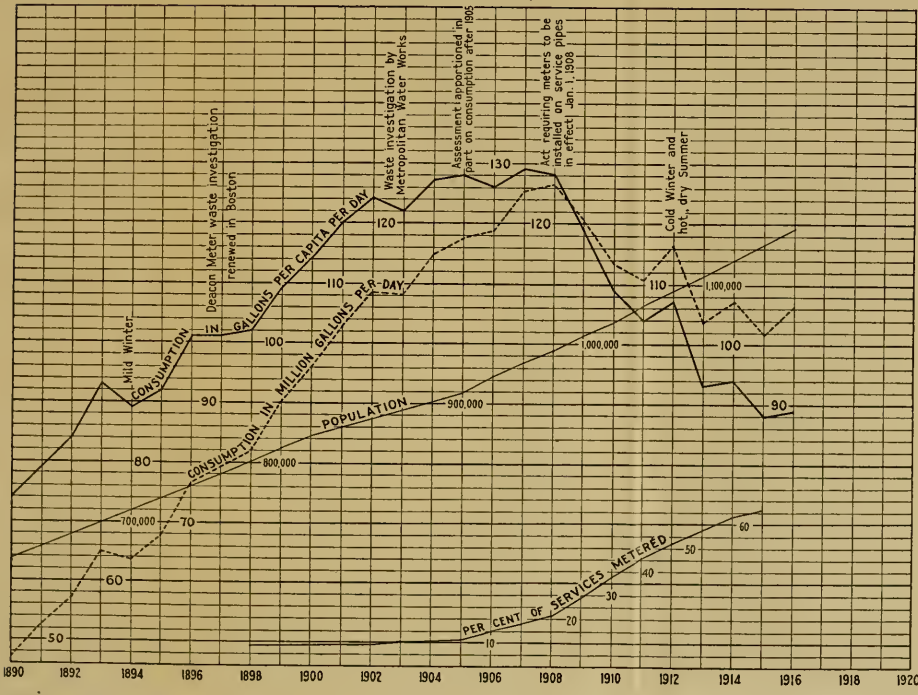
Waste of water can be divided into two classes, — leakage from mains and waste from service pipes. The first can be stopped by efficient management and the latter by enlisting the consumer's coöperation by giving him a direct pecuniary benefit. It appears to the writer that the best way to get results is to sell the water by measure and to keep the measuring devices in good working condition. The writer maintains that the waste which has been stopped in the Metropolitan Water District of Boston by the installation of service meters has deferred for the present the construction of additional works and reduced the cost of maintaining existing works.

Discussion.

Mr. Frank L. Fuller. This question of night consumption seems to me a very interesting one. Records at Wellesley show that there is a considerable consumption at night, it is a large proportion of the total daily consumption, and it does not seem as though it could all be due to leakage in the pipes, neither does it seem as though it could be due to waste in the houses. Yet it appears to be very difficult of solution.

Mr. Killam. It must be one or the other. I think the most interesting work on a distribution system is the accounting for

POPULATION, CONSUMPTION OF WATER AND PER CENT OF SERVICES METERED IN THE METROPOLITAN WATER DISTRICT AS SUPPLIED IN 1916 FROM 1890 TO 1916



water delivered into the system. Recently, in a town in the Metropolitan Water District, where the night consumption was high, we divided the town into six sections, and found that most of the water was used or wasted in two of the sections. We will later subdivide those sections into smaller divisions and test the smaller sections until we find the leaks. In the cities and towns supplied from the Metropolitan water district where the services metered are nearly 100 per cent., many of the places are unable to account for 30 per cent. of the water delivered through the master meters.

Mr. Fuller. At Wellesley we have everything metered except the drinking fountains, and yet we cannot account for all the water that is pumped. I suppose some of the discrepancy is due to the non-registration of very small flows.

Mr. W. A. McKenzie. When the state law was passed in regard to the consumer paying for the amount of water used, did that law also carry a provision for minimum rates for various sizes of pipes and services, and different classes of houses? Is the meter rate the same for all residential districts?

Mr. Killam. It did not. In 1895 the act provided the Metropolitan Water Board should approve the minimum rate established in each municipality, and each city or town is required to submit a minimum rate for approval, which depends on the local requirements, as many of the cities and towns are still under a bonded debt. So there has been no uniform minimum rate established for the entire district.

Mr. McKenzie. Do you know what those minimum rates are for the same sizes of house services in the residential districts?

Mr. Killam. The lowest minimum rate is $6 a year for 5 454 cu. ft., equivalent to $0.11 per 100 cu. ft., and the highest minimum rate for 100 cu. ft. is 0.33\frac{1}{3}$.

Mr. S. H. McKenzie. I would like to inquire where they set the meters, — inside or outside the house? If outside, how do you set them?

Mr. Killam. That is a question for the the local superintendent in the several cities and towns to decide. I see Mr. Merrill, of Somerville, here, and I know he would be very glad to answer that question.

Mr. Frank E. Merrill. I would say that in Somerville we make a practice, as far as possible, of setting all meters inside, in the cellars of the houses, and as near to the point of entry of the service pipe as possible. There are some cases where it is not convenient to install meters inside the house, and in those cases we set them in the sidewalk, in either a box made of tile pipe with an iron frame and cover, or in a wooden box. Out of 10 000 meters installed in the city, we have 300 outside installations.

President Saville. Are there any other questions? The chair would like to ask Mr. Killam a question. You spoke of the Deacon meters. Are these meters in service now in your district?

Mr. Killam. They are connected but not in use.

President Saville. You will not use them on your night work?

Mr. Killam. No. We are using a series of ordinary disk meters and depending on the Venturi meters to measure the consumption in the larger districts.

President Saville. Mr. Fuller, I think, asked a question about the relation of the night loss. Perhaps Mr. Cole would tell us something about that.

Mr. E. S. Cole. I don't think I can give you any valuable information on the night rate now. If the night rate is 50 per cent. of the twenty-four hours, we consider it very satisfactory.

President Saville. I think Mr. Fuller's question was whether that night rate, which seems comparatively large, was generally all made up of leakage from services and house connections, or whether a good part might be consumption.

Mr. Cole. We find it is a very difficult thing to get the minimum night rate below about 50 per cent. of the average rate.

President Saville. Referring to Mr. Killam's statement about the waste of water in the Metropolitan District, in 1902 and 1903, I have particularly in mind some tests that were made in Melrose, Mass. They had no meters in use at that time, and the distribution system was tested by shutting off the mains in each street. The test showed a consumption of five or six cubic feet a minute on one short street which had about twenty-five houses on it. The leakage was reduced about two thirds by shutting off all the house services at the curb, which meant that two thirds of

the leakage on that street was in the houses themselves. The foreman before shutting off the services listened at each one, and he heard leakage from two of them, and it developed later that one leak was in the gooseneck at the main, and another was between the corporation cock and the house. We repaired the leak at the main, and on a test made the next night we found no leakage. Now, two thirds of the leakage on that street was in the houses and was probably small streams running in closets or from other fixtures in the house. If there had been meters in the houses at that time it would have been interesting to read the meters to see how much of that leakage was registered. I think that follows on Mr. Cole's thought that it is an aggregate of small leaks, small quantities of water that it is hard work to find.

Mr. W. C. Hawley. For several years our company has followed the policy of making an annual Pitometer survey. Our system is divided into districts, so that year by year, as each of those districts is tested, we have the previous tests to go by, as indicating whether or not there has been any material change. Our district is practically 100 per cent. metered. The result is that we find a very low night flow, and yet it is a very considerable flow. And our experience leads us to believe that while a part of it is due to service leaks, and occasionally to a leak at the joint, the most of it is in the houses and is in streams that are too small to be measured by the ordinary water meter. The ordinary water meter that has been in service for a time won't measure a stream running two, three, or four gallons an hour, and that amount in a good many houses soon mounts up to a considerable volume of water. But we do find frequently service leaks, — leaks under service lines running into sewers, or getting away somewhere, that we would never find without the Pitometer. And by making these surveys we have been able to account for from 80 to 82 per cent. of the water that we draw from our r servoir.

Mr. William J. Willson. I might state for the information of the members a little experience in 1911 when we put a Pitometer on the system, by which we stopped a leakage of one million gallons in twenty-four hours. In this case all of the leaks that were found, with one exception, were from abandoned services

under paved streets and the water was running off into the sewers or other structures. The exception was the case of a 16-in. joint, virtually blown out. This experience shows that it is well to cut off abandoned service lines at the mains.

President Saville. Perhaps the speaker would also agree that it would be well not to accede to some of the requests of street departments, where they are going to pave streets, to put in services ahead of the paving, so that you won't have to take the paving up.

Mr. H. F. Dunham. In regard to leakage on house services. We have had occasion to make a number of Pitometer surveys of our works, and we were very well satisfied when we reduced our night consumption to 30 per cent. of the average. In making these surveys we found that the leaks are generally small leaks. The question has been raised here in regard to keeping the fixtures in the houses in good repair. There is a limit to that in which the property holder, the owner, may be burdened much in excess of the value of the water that is wasted in the fixtures. If a man is paying 20 cents extra, say, upon his monthly bill, it will take a good many monthly bills to pay one plumber's bill, and the question arises whether or not when you ask the consumers to keep their fixtures so that there is no leakage, you are not imposing a burden on your customer which is unnecessary and unreasonable. That is the question that has confronted us a number of times. So that I believe from my experience of many years that if you can reduce your minimum night consumption to 30 per cent. or less of your daily average consumption you have done about all that you can expect to do.

Mr. McKenzie. I have noticed a large amount of this night consumption has taken place in toilets, and I was wondering whether anybody here had ever made a rule of any kind as to the kind of toilet that should be installed, or has found a valve that can be kept tight for any length of time. Sometimes if you repair them they will stay in repair only a short time. It seems to me that is one thing that might be taken up and a great deal of water saved, if some valve which could be kept tight could be found.

Mr. Dunham. I would like to ask, while on this subject,

if this matter could not be largely controlled under the conditions under which the works are operated, whether you have a high pressure or low pressure. I will say that we have had a condition that was rather unusual and rather hard on the fixtures. We carry a pressure of about 60 lb. We furnish a direct fire pressure for every alarm, and that pressure is raised from 60 to 110. The result is that these fixtures get a great shock, sometimes three or four times a day, and we have a much higher leakage than if we could maintain a constant pressure.

PROCEEDINGS.

Thirty-Sixth Annual Convention.

Hartford, Conn.,
September 11, 12, 13, 14, 1917.

The thirty-sixth annual convention of the New England Water Works Association was held at Hartford, Conn., September 11, 12, 13, and 14, 1917.

The sessions of the convention were held in Unity Hall, Pratt Street, where also were provided accommodations for the exhibits of Associates.

The following members and guests were present:

Honorary Members.

Frank E. Hall. George A. Stacy. R. J. Thomas. — 3.

Members.

G. H. Abbott.	L. G. Carlton.	A. B. Farnham.
J. M. Anderson.	C. E. Chandler.	C. A. Farnham.
F. E. Appleton.	E. S. Cole.	A. D. Flinn.
M. N. Baker.	P. J. Conlon.	A. P. Folwell.
L. M. Bancroft.	H. R. Cooper.	H. F. Frost.
Stephen Barden.	G. K. Crandall.	F. L. Fuller.
C. F. Barker.	H. C. Crowell.	F. C. Gamwell.
H. K. Barrows.	A. W. Cuddeback.	W. A. Gardner.
G. W. Batchelder.	John Cullen.	Patrick Gear.
G. H. Bean.	F. A. Darling.	H. T. Gidley.
F. D. Berry.	M. W. Davenport.	F. J. Gifford.
F. E. Bisbee.	C. E. Davis.	T. C. Gleason.
A. E. Blackmer.	F. J. Davis.	H. J. Goodale.
C. M. Blair.	J. M. Diven.	F. S. Goodwin.
Bertram Brewer.	John Doyle.	S. M. Gray.
T. L. Bristol.	H. F. Dunham.	L. M. Hastings.
H. R. Buck.	J. S. Dunwoody.	E. L. Hatch.
Alvin Bugbee.	C. W. Eddy.	A. R. Hathaway.
E. L. Burnap.	E. D. Eldredge.	W. C. Hawley.
L. W. Burt.	R. H. Ellis.	A. B. Hill.
C. J. Callahan.	W. B. Ellis.	T. E. Hopkins.

J. L. Howard.
W. F. Howland.
H. W. Horne.
J. A. Hoy.
J. L. Hyde.
J. F. Jackson.
A. W. Jepson.
G. A. Johnson.
W. E. Johnson.
W. S. Johnson.
T. N. Kapoustine.
Willard Kent.
J. A. Kienle.
S. E. Killam.
A. C. King.
G. A. King.
H. M. King.
G. H. Leland.
M. B. Litch.
B. C. Little.
E. L. Lockridge.
F. H. Luce.
P. J. Lucey.
S. H. MacKenzie.
H. V. Macksey.
E. T. McDowell.
C. R. McFarland.
Thomas McKenzie.
W. A. McKenzie.
J. N. McKernan.
Hugh McLean.
A. E. Martin.
J. H. Martin.
T. P. Martin.
J. H. Mendell.
F. E. Merrill.
G. F. Merrill.
Alexander Milne.
H. A. Miller.
M. L. Miller.
E. E. Minor.
P. T. Mullin.
J. A. Newlands.
R. J. Newsom.
F. L. Northrop.
W. H. O'Brien.
E. M. Peck.
A. E. Pickup.
J. F. Ranger.
W. H. Richards.
L. C. Robinson.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
W. P. Schwabe.
J. E. Sheldon.
M. A. Sinclair.
E. W. Smith.
G. H. Snell.
H. T. Sparks.
F. N. Speller.
H. C. Stevens.
E. L. Stone.
J. F. Sullivan.
W. F. Sullivan.
G. A. Taber.
A. T. Thompson.
J. L. Tighe.
E. J. Titcomb.
R. K. Tomlin, Jr.
D. N. Tower.
F. M. Travis.
Louis Treal.
H. R. Turner.
C. H. Tuttle.
J. H. Walsh.
R. S. Weston.
R. C. Wheeler.
F. H. White.
J. G. Whitman.
R. W. Wigmore.
W. A. Wilcox.
W. J. Willson.
I. S. Wood.
L. C. Wright. — 148.

ASSOCIATES.

Allen & Reed, Inc., Z. M. Jenks.
American Bitumastic Enamels Co., F. G. Ricker.
The American City, J. H. Van Buren, T. R. Kendall.
Builders Iron Foundry, A. B. Coulters, F. N. Connet.
Carbic Mfg. Co., E. G. Frey.
Central Brass Mfg. Co., M. J. Hirschfield, Joseph Mayer, R. M. Corcoran, V. J. Mahler.
Central Foundry Co., R. W. Conrow, Stuart Root, W. H. Feltt, H. Y. Carsons.
Chapman Valve Mfg. Co., V. N. Bengle, C. E. Pratt, H. U. Storrs.
Chicago Pneumatic Tool Co., H. W. Buker.
Darling Pump & Mfg. Co., Ltd., H. D. Thorp, H. A. Snyder.
Dixon Crucible Co., Joseph, H. A. Nealley, C. A. Shaw.
Eddy Valve Co., H. R. Prescott, H. A. Holmes.
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Engineering News-Record, I. S. Holbrook, Wm. Buxman.

Fire and Water Engineering, I. H. Case, Fred Shepperd.
Garlock Packing Co., F. S. Bulkley.
Goulds Mfg. Co., The, C. W. Fulton.
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Hersey Mfg. Co., J. H. Smith, W. A. Hersey, W. C. Sherwood.
Kennedy Valve Co., M. J. Brosnan.
Leadite Co., The, George McKay, Jr., J. P. McKay.
Lead Lined Iron Pipe Co., F. N. Du Bois, T. E. Dwyer.
Lock Joint Pipe Co., G. C. Bartram.
Ludlow Valve Mfg. Co., A. R. Taylor, J. H. Caldwell.
Mueller, H., Mfg. Co., W. N. Fairfield, G. A. Caldwell.
Municipal Journal, J. T. Morris, J. L. Collins.
National Meter Co., J. G. Lufkin, H. L. Weston.
National Tube Co., H. T. Miller.
National Water Main Co., B. B. Hodgman.
Neptune Meter Co., H. H. Kinsey, T. D. Faulks, Charles Bachmann.
Norwood Engineering Co., H. W. Hosford, F. M. Sears, H. G. Meuke.
Pitometer Co., The, E. D. Case.
Pittsburgh Meter Co., T. C. Clifford, J. W. Turner, V. E. Arnold.
Pratt & Cady Co., Inc., E. L. King, W. D. Cashin, O. L. Beach, M. R. Cook.
Rensselaer Valve Co., C. L. Brown, I. A. Rowe, J. S. Warde, Jr.
Ross Valve Mfg. Co., William Ross.
Schramm & Son, Chris D., J. W. Gleason.
S. E. T. Valve & Hydrant Co., C. L. Lincoln, P. B. Madden.
A. P. Smith Mfg. Co., F. L. Northrop, D. F. O'Brien, A. C. Nieman, T. F. Halpin.
Thomson Meter Co., S. D. Higley, E. M. Shedd, F. M. Watson.
Union Water Meter Co., E. W. Jacobs, D. R. Otis.
United Brass Mfg. Co., H. M. Flemming, H. A. Bogdonoff, J. A. Sharp.
United States Cast Iron Pipe & Foundry Co., Charles Donaldson.
Wallace & Tiernan Co., Inc., M. F. Tiernan.
Warren Foundry & Machine Co., W. F. Woodburn.
Water Works Equipment Co., W. H. Van Winkle, W. H. Van Winkle, Jr.
Wood, R. D., & Co., C. H. Becker, C. R. Wood.
Worthington Pump & Machinery Corp., Sanuel Harrison, W. F. Bird. — 94.

Guests.

Maine.

Lewiston, Gertrude Callahan, Helen Callahan.

New Hampshire.

Derry, Mrs. G. H. Bean.
Manchester, Mrs. J. H. Mendell, G. A. Woolner.
Nashua, Mrs. W. F. Sullivan.

Massachusetts.

Boston, H. A. Burnham, Mrs. G. A. Caldwell, Mrs. C. W. Fulton, Mrs. W. S. Johnson, Mrs. S. E. Killam, R. M. Kinsman, G. H. Richey.
Cambridge, Mrs. L. M. Hastings.
Cohasset, Mrs. D. N. Tower, Miss M. P. Tower.

Florence, W. G. Ryan.
Framingham, Mrs. W. F. Howland.
Franklin, Miss Kathleen Darling.
Greenfield, Mrs. G. F. Merrill, W. T. Noyes.
Haverhill, H. B. Crowell, F. T. Hamlin, W. A. Tweed.
Holyoke, L. W. Bacon, Mrs. Hugh McLean, Miss Marion McLean, Mrs. J. F. Ranger, Mrs. J. E. Sheldon.
Lowell, Mrs. F. E. Appleton, J. E. Sullivan.
Marlborough, Mrs. G. A. Stacy.
Melrose, Mrs. J. L. Howard.
Onset, Neddie Eldredge.
Palmer, Mrs. F. C. Gamwell.
Pittsfield, Mrs. A. B. Farnham.
Plymouth, Mrs. E. A. Blackmer.
Reading, Mrs. L. M. Bancroft.
Southbridge, Mrs. C. H. Abbott.
Springfield, Mrs. H. M. King, W. E. Moore, May Potter, Mary A. Shea, C. W. Winslow.
Ware, Mrs. John Gleason.
Wellesley, Mrs. F. L. Fuller.
West Springfield, W. H. Bagg, B. E. Fox, G. N. Norris, J. F. Whitney.
West Brookfield, J. E. Malloy.
Woburn, Mrs. H. V. Macksey.
Worcester, Mrs. John Doyle, W. H. Larrabee.

RHODE ISLAND.

Narragansett Pier, Mrs. Willard Kent.
Providence, G. F. Hiller.
Westerly, Mrs. Thomas McKenzie.
Woonsocket, Mrs. Z. M. Jenks.

CONNECTICUT.

Ansonia, Mrs. F. J. Davis.
Bristol, D. F. Crowley.
Bridgeport, Mary A. Martin.
Bristol, C. L. Wooding.
Danbury, T. S. Durant.
East Hartford, Charles Barnes, Mr. and Mrs. Albert Clay, Mrs. James Fogarty, Miss Annie . Fogarty, Miss Nellie Fogarty, L. S. Forbes, James Johnston, E. E. King, Mrs. Joseph Walsh, Mrs. J. H. Walsh, Miss Madeline Walsh, George Westbrook.
Hartford, A. H. Blease, F. S. Brainard, J. A. Collord, W. J. Crawford, Harold Evans, Arthur Fifoot, E. J. Flynn, H. R. Freeman, W. F. Gunn, R. F. Hazard, A. E. Knowlton, J. A. Lawler, Miss E. L. Mulcahy, Miss Christine Newton, Miss S. I. O'Brien, Charles E. Rogers, Charles Rogers, Mandel Sener, F. E. Shea, J. J. Sheedy, C. D. Sherman, D. J. Sullivan.
Meriden, Clarence Carpenter, Mr. and Mrs. J. B. Gleason, J. W. Holden, J. A. Tower.
Middletown, J. J. Griffin, Mrs. Harry Mayoll.
New Britain, T. H. Kehoe, W. B. Rossberg, J. H. Towers.
New Canaan, Ben Keeler.
New London, Mrs. G. K. Crandall, S. C. Starr, G. E. Watters.
New Haven, Mrs. C. M. Blair, L. D. Burke, Mrs. J. F. Dorrigan, Mrs. J. F. Jackson, Miss Anna C. Lee, Lloyd Logan, E. A. Toole.
Norwich, Mrs. E. L. Burnap, Mrs. C. E. Chandler.
Plainville, Mr. and Mrs. E. H. Hills, Mrs. J. N. McKernan.
Rockville, Mrs. A. T. Thompson, Robert C. Thompson.
Southington, Miss Eleanore MacKenzie, Miss E. J. MacKenzie, Miss F. L. MacKenzie, Mrs. S. H. MacKenzie, D. F. Shanahan.
Stamford, B. H. Keeler.
Thompsonville, C. A. Goodhue, Richard Norris, Mrs. W. P. Schwabe.

Torrington, W. E. French.
Wallingford, J. P. Bridgett, J. E. Martin, Mrs. W. A. MacKenzie, A. E. Sutterlin.
Windsor, P. F. Ellsworth, Mr. and Mrs. J. A. Oaks, Mrs. W. P. Mott, Mrs. H. R. Turner.

NEW YORK.

New York City, W. F. Barnwell, Mr. and Mrs. H. B. Coho, P. P. Dean, Ellis Hyers, J. J. Walsh, D. F. Wilcox.

NEW JERSEY.

Montclair, Mrs. W. C. Sherwood.
Newark, James Woolley.

PENNSYLVANIA.

Erie, G. C. Gensheimer.
Philadelphia, W. W. MacCallum, E. W. Nichols, Miss Anna Nichols,
Steelton, Mrs. M. B. Litch.

OHIO.

Youngstown, Mrs. T. S. Chamberlain.

ILLINOIS.

Evanstown, John Gaitenby.

NEW BRUNSWICK.

St. John, E. J. Terry. — 160.

TUESDAY, SEPTEMBER 11, AFTERNOON SESSION.

The convention was called to order at 2 P.M. by Caleb Mills Saville, the President. In opening the convention President Saville spoke as follows:

Gentlemen, — This is the opening of the thirty-sixth annual convention of the New England Water Works Association, and greeting us here are representative men of the city of Hartford, — men of local prominence and also those whose names are of national significance in the field of politics, law, literature, and business. Hartford is preëminently a business man's city, and out of the very midst of its bustle and work these men, representative of scores of others, have come to give us welcome.

Personal traits often are accentuated by public life, and trial in this furnace is one of the most severe tests of human character. We, therefore, greatly respect him who comes forth upright and unsmirched, especially when moved as by an irresistible impulse to do things not for personal glory but for the good of the community. Such a man is he whom I now have honor in presenting to you, — lawyer, progressive official, exponent of the highest type of public servant, — the Hon. Frank A. Hagarty, mayor of the city of Hartford.

ADDRESS OF WELCOME BY HON. F. A. HAGARTY.

Mr. President, Ladies and Gentlemen, — I thank your chairman for this very flattering presentation to you. It is only the kind of thing, however, which we have come to naturally expect from the amiable and capable manager and superintendent of our local water system.

It is a very great pleasure indeed, in behalf of this municipality and its people, to bid the members, the delegates, and their friends of this New England Water Works Association a cordial welcome to the city of Hartford. We always take pleasure in bidding a welcome within our gates to men or women who are banded together for a patriotic or a useful purpose, and it is particularly gratifying to us to have this opportunity to offer a welcome to you who are interested in a work which is so near to all of the people who live in the large centers of population throughout the country.

In these troublous times through which we are now passing and through which the world is passing, the conventions do not always show what they advertise beforehand; but we have no hesitation in bidding you welcome, because we know that no seditious word, no word other than words of patriotism, so far as they relate to our country and the crisis through which it is passing, will be heard in this convention. And that ought to be true of every convention that is convened in any corner of this country during this crisis.

The people who live in the larger centers of population, not only in this country but in every civilized country, have become so used to taking as a matter of course the various facilities which make it possible for urban populations to live as they do, that they scarcely stop to think, to count, if you please, the things that go to make it possible to live in a community like Hartford, — such things as proper transportation facilities, gas and electric power, and perhaps more important than any other, an abundant supply of pure water. Without an abundant supply of pure water it would be practically impossible for these municipalities which exist in every state of our country to live the kind of a life that their people do live in this twentieth century.

And so the business that you are engaged in fostering and in studying and in trying to make better is, perhaps, the most important feature of community life; and because this is so it is doubly a privilege and a pleasure to bid you welcome to this fair city, which was one of the pioneer communities of this country in the establishment of a municipal water system. I will not go into that this afternoon further than to record the fact that before the century which preceded the present one had begun there had been established here, on a small scale to be sure, a water-works system. Along in the middle of the last century — of the nineteenth century — there was projected and built a splendid water-works system which supplied our city for the next fifty or sixty years, and at the present time we are engaged, under the able management of our present board of water commissioners, and under the able guidance of your honored President as manager, in the construction of a very much more extensive water system, which is to be brought to us over many miles of country and which is to cost from two to three millions of dollars. When it has been completed it is expected that it will adequately supply the wants of the people of Hartford and of its varied industries of many kinds for the next fifty or sixty years. And it seems to me particularly opportune that you should come here at this time when we have these works in the course of construction. It may very well be that some suggestion which may arise out of your visit here will prove of large benefit to our people and to our community so far as this particular work in which we are now so much interested is concerned. But, however that may be, it cannot but result that a gathering of this kind will bring together the various communities which you represent in this organization. The exchange of ideas which is brought about by gatherings of this kind cannot fail to be fruitful of good results.

I hope that you will find this convention place which you have chosen, this city which you have chosen as your convention place, as pleasant as the cities which you have become used to as convention places. We who live here in the city of Hartford, and have lived here all our lives, naturally think that this is the most beautiful city that can be found anywhere. There are undoubtedly ladies and gentlemen here who are familiar with the best cities on

this continent, and other continents as well, and I will only say in passing that during your sojourn here I hope, and the people of Hartford hope, that you will at least find Hartford a pleasant city in which to hold your convention.

And so, gentlemen, not to detain you from the proceedings of the afternoon session, I will conclude by again saying that it is a very great pleasure to welcome you to the city of Hartford, to express the hope that your deliberations will be profitable to yourselves and to the communities which you represent, and that when you go you will take away with you such pleasant impressions of the city of Hartford and its people that you will be constrained to pick out the capital city of the state of Connecticut as a place for holding some future convention of your Association. [*Applause.*]

President Saville. The president and editor of the oldest daily newspaper in America, a man of strong principle and of the highest character, trustee and overseer of Yale University, exponent of the literati of America, — I take the greatest pleasure in introducing the Hon. Charles Hopkins Clark.

ADDRESS OF WELCOME BY HON. CHARLES HOPKINS CLARK.

Mr. President, Ladies and Gentlemen, — When I have recovered from the blushes that the chairman placed upon me I will say a few words, if you please. I am very glad to join in the welcome to you all here to Hartford, and I am especially glad that our system of water works is going to be inspected by a body of such intelligent experts as you gentlemen here. I do not fear at all what your verdict will be. Hartford is a progressive city and up-to-date in all respects, and I am confident that the result of your inspection will be to add new force in that direction.

I am here, as Mr. Saville has said, to-day simply because I have an hereditary connection with the business. Hartford decided, back in 1854, to establish municipal water works, and my father was the president of the first board of commissioners, and they built a reservoir up on Asylum Hill, — the highest available land, — to which they pumped up the pure water of the Connecticut River; and then they sent it back again defiled and polluted, to the distress of our neighbors farther down the stream. Well, that was 1854, but it was not long before they found that that

was going to be inadequate to the demands of the growing city, and they decided to pond the whole watershed of the West Hartford Hills, out beyond us here, which you will see during your visit. The first reservoir was built there in 1865. There is now a chain of reservoirs, — six altogether, — ponding at different places the water from these streams that come together there. The trouble with ponded water is that you have to have such an enormous quantity of it. What with the evaporation which is going on all the while, — and which is worse during a drought than any other time, — and with the occasional droughts which we have here, it became evident before long that we had got to have something greater than all the water that could be stored there. My father came into the presidency of the board a second time in 1882 and remained there until his retirement in 1895, being eighty years old and through with business. How many of those reservoirs out there he built, I don't know; but I do know that he laid out and constructed the reservoir park, which I hope you will all see, and which seems to me an adequate monument for any man's service to the city. It is one of our beauty spots.

In the way of business, the city of Hartford adopted the plan of compelling every customer to use a water meter. Now, I understand there are places where that is not done, where you pay so much for all the water you use. Suppose that they did that with gas, suppose they did that with electricity, — it is an utterly unbusinesslike method. And they adopted the plan here — which is straight business — of paying for what you get. Mr. Saville has shown me a chart showing that at the time that rule was adopted Hartford was using seventy-nine to eighty gallons of water per capita per day, and to-day it is using only sixty-six gallons per capita per day, a saving of thirteen or fourteen gallons a day for each person, which in a large city like this means an immense amount of water saved.

It became evident that, with the evaporation and with the need of pumping from the river, we had to do something more, and not long ago the great scheme at Nepaug, which you will inspect on Friday, was developed, and it is approaching completion. I am very glad that such a body of intelligent men is going to see it, and I am sure you will be impressed by it. Hartford is bound

to have enough water. Recent legislation at Washington indicates that there will be some increase in its use whether the population increases or not. [*Laughter.*]

Now, I asked Mr. Saville in regard to the fact of the development of water works. Hartford had a water-works system back before 1800. Occasionally in their work they would dig up a hollow log, and they would find that it was a part of a system for supplying water through hollow logs. And I believe they had one or two similar private companies in other cities. But Hartford was the first city hereabouts that undertook water works with the iron supply pipes and the paraphernalia that goes with it. Hartford established them in 1854, New Haven established a private company in 1860. The New Haven company to-day is very prosperous, gives plenty of water, good water, and is successful in all respects. But it is a creature of slow growth.

My friend Mr. Gross, here, and I were in college together. I graduated from Yale in 1871, and I up to that time did not know there was a system in New Haven. The Yale College boys depended on the old college pump, and the water from the old college pump was never analyzed, although its results were abundant, because a part of the course there was typhoid fever. [*Laughter.*]

Waterbury established water works in 1868, Providence in 1870, New London in 1872, Springfield in 1873. So that here again is evidence of the progressive spirit of Hartford.

Now, it is your business to see that communities have adequate good water supplies. But that is not the end of the business. Before 1854 Hartford had about forty sewers which carried off the extra surface water from storms; to-day we have one hundred and ten miles of streets, and the city engineer tells me that there is a sewer in nearly every street in the city. Think what that means. All the one hundred miles or more of pipe used every day to pour filth into the Connecticut River! And what Hartford is doing, every other city is doing, and the Connecticut River is to-day an open sewer for the Connecticut Valley; and all the other rivers we have in this state are doing the dirty part in that work. Somebody has got to come along who will get at the other end of the proposition, who will take the sewerage and put it into fit shape to be used again, who will purify the water and get

back on to the land that which the land needs. I have the feeling that the convention which is to be held here will tend strongly to bring about that result, — that we will get back on to the land that which the land needs, resulting not only in giving us purer water, but in improving the soil and giving us cheaper foods.

I thank you, gentlemen, for your attention, and I hope you will follow out the mayor's suggestion and see all you can of Hartford. We are very modest people, but I do venture to say that the more you see of Hartford the more you will think of it. We shall be very grateful to you for any good opinions that you carry away. [*Applause.*]

PRESIDENT SAVILLE. A distinguished jurist, president of the Connecticut Bar Association, sagacious man of business, reliable and trusted adviser, a man whose friends are legion and whose life exemplifies the highest ideals and standards, — I am honored in presenting to you the Hon. Charles E. Gross.

ADDRESS OF WELCOME BY HON. CHARLES E. GROSS.

MR. GROSS. *Mr. President, Gentlemen of the Water Works Convention, and Ladies,* — I have made a mistake, Mr. President, at the very opening. I am embarrassed in my opening sentence. And that reminds me that a short time ago I was present at a dinner where there were twenty-two young ladies, where the Rev. Joseph Hopkins Twitchell spoke. And when Mr. Twitchell commenced his address he said, "Gentlemen and ladies." Then he said, "Now, I am in it." And that reminded him of a story in a grammar class. The end of the week had come and the teacher wanted to review what she had attempted to teach the children during the week. And she had the girls and boys before her, and she said to them, "Now, I am going to give you some sentences which will have grammatical errors in them, and I want you to point them out. For instance, 'The horse and the cow is in the pasture.'" No one raised a hand. "Why," she said, "don't any of you see any grammatical error there? Let me give it to you again. 'The horse and the cow is in the pasture.'" One little fellow raised his hand and she said, "Jimmy, where is the mistake?" He said, "The lady should have been mentioned first." [*Laughter.*]

And, Mr. Chairman, you have also embarrassed me by your introduction — I should not have known to whom you referred had it not been the mention of my own name. But you will all, I think, recognize that, like another very distinguished engineer — the late Hopkinson Smith — your President is an artist along many lines, and to-day he has commenced by being a creator of fiction, — if you will pardon me.

Now, I expected a very different introduction than he gave, — a very different one. I supposed that I was invited here possibly as the oldest native inhabitant, who can tell you of the conditions here in Hartford before the father of my distinguished friend wrested us from it in 1854. Or I thought possibly I might be introduced as one of the "goats." Now, I am a lawyer, and you know lawyers are divided up into classes according to the special work that they do. We have counsel, and we have barristers. A barrister is one, as you know, who tries out questions of fact in the courts. Possibly you never heard the difference between a counsellor and a barrister. If you never heard the answer, I will tell you. Some one said that the difference was exactly the same as between a goat and a bulldog, — one fought with his head and the other with his mouth. [*Laughter.*] Now, my firm for the past generation has been counsel for the Board of Water Commissioners of Hartford, and although the work of fighting has been done by my partners, yet I claim to be enrolled in the class of goats. But possibly when you know that my special study has been hydraulics, you will say that I do not belong in the class of goats but should be classed by myself as a ram. [*Laughter.*]

I said I expected to have been introduced to you as the oldest native inhabitant, and so I had prepared to tell you of the conditions here in Hartford before the organization of the Board of Water Commissioners. I could have told you of the old public cisterns along our highways for fire purposes, also the old cistern which was connected with every dwelling house, where they collected the rain water from the roofs for culinary and laundry purposes. I could have told you of the old deep wells with the cold water many feet down, and which wells were also used as refrigerators in the summertime, where the cream and the milk and the meat were kept, being lowered in a basket to near the water's edge, for their preservation during the hot season.

And then following along later I could have told you of many things that preceded the formation of our water works, — how the distinguished Dr. Bushnell had a far-sighted vision of making along the banks of the Connecticut River a modern Manchester of England, for, with the aid of engineers, his proposition was to turn the entire ordinary flow of the Connecticut River into a large canal, extending from the Enfield Falls to Hartford, along the line of which were to be numberless hydraulic sites, and occasionally a water reservoir for the community for drinking water. And into those reservoirs he proposed to force the water from the canal by means of pumps in wheel-pits, which were to be fed from the canal, and power generated for driving the pumps. Now, that was a great vision; it was worthy of the great man that he was. But in 1840 the conservative investors of this section could not see the return for their enormous expenditure of money.

Then I could have told you of the vicissitudes of the earlier boards of commissioners, the criticism that they were constantly subjected to, the injunctions which stopped their work from time to time, the demand for other reservoirs within our city limits, or greater pumps, and later the urgent demand for a more sanitary supply of water.

And so we built the reservoir in West Hartford, and shortly after the completion of the second, and shortly after the water was turned on in 1867, came the destruction of those reservoirs, and all the trouble that followed thereafter. And, as Mr. Clark has told you, that initial reservoir grew in number to six, and still we are not satisfied. We demanded more water, more water, more water. And how that demand has been met I trust you will all have the privilege of seeing for yourselves later in the week, and I am satisfied that your opinion will be that, as to this new system of water, Hartford is up to date.

Now, good water works are the best physical asset that a city can have, and I am satisfied that the value of the Nepaug system to the city of Hartford will never depreciate until the Martians come here and instruct us as to their skill in building waterways. But I think we must not be contented with this system which we have to-day; I think there is a greater question that necessarily must be taken up soon by all cities. I think the conflagra-

tion in San Francisco has taught us the danger of a city depending upon a pipe line entirely for water. We know that the line from Nepaug comes through trap-rock which once was subjected to volcanic action. And as the earth cools — I don't know when or how soon — we shall have another upheaval, and what will be the result to the pipe line from Nepaug, I don't know. I think every city should have a dual system. I think we should have one system for household purposes and another system for the manufacturers, for fire hydrants, for street cleaning. I do not believe that the good water from Nepaug should be used for any such purpose. In fact, I never see Poland water used for washing the piazza of the hotel there but that I think it is a criminal waste. And, as I said before, we should be independent of a pipe line which comes as many miles as that from Nepaug. We have here in Hartford the Connecticut River; we have already a very large pumping station; we have a reservoir on the hill, as Mr. Clark has said, at our highest peak; we have mains that very soon, I think, will have to be discarded for new mains because the pressure of the water from the west will be so great. Now, I do hope that our pumping station will never be sold. I trust that those mains in our streets will never be taken up nor the Garden Street reservoir leveled. I want them all preserved so that we can have within our limits fire protection and a creditable supply of water for the baser uses.

You may say to me that we should be thankful for what we have got. We are. We rejoice at this new system which has just been completed. And we rejoice that within a very few weeks there will be no need in Hartford of our asking for Apollinaris water, nor French, Italian, or even Poland. We shall have to offer to every guest within our gates a glass of pure, cold water from Nepaug, and I am satisfied that when that water is drawn no one will have cause to complain that the distilleries stopped business last Saturday night. [*Laughter.*]

Now, who has brought us to this very happy condition? When this Nepaug work was first mapped out, every one saw that it would be necessary to secure the services of not only a competent engineer, but one who could also be said to be an artist in his line. There was only one place then open to find such a man, — the

congregation of eminent engineers was at Panama, and we went there. We found in that glorious Southern Cross a star of great magnitude, and, following the motto of our state, we translated that star from the Southern Cross to the northern Dipper in order that he might furnish a greater supply of water to Hartford. Now, we know that what is well begun is half done already. Mr. Saville, your President, in a few days will take great pleasure and pride, and justly so, in showing you the development of the Nepaug system; but, gentlemen, I take greater pride this afternoon in telling you that the successful execution of that great work is due to your President, Mr. Saville. [*Applause.*]

President Saville. I think that my friend, Mr. Gross, has put the matter of embarrassment the other way, if you please. He told you how embarrassed he was and what he thought of what had been said about him. You can only judge from that how to take his own words. He told you what he could tell you about; he doesn't tell you about what he can tell you about. That is, how one of the largest hydraulic propositions in the country — the Holyoke Water Power Company, of which he is president — has expanded under his able management.

Progressive and able man of business, open-minded and keen in judgment, upright and clean in all his dealings, excellent representative of the men whom Hartford calls to administer her municipal business,— I take pleasure in presenting to you Mr. James P. Berry, acting president of the Board of Water Commissioners.

ADDRESS OF WELCOME BY MR. JAMES P. BERRY.

Mr. Berry. *Mr. Chairman and Gentlemen,* — In the absence of the President of the Board of Water Commissioners, Mr. Frank E. Howard, I have been asked to come here this afternoon and extend to you gentlemen a cordial greeting, and to earnestly request that each and every one of you will pay a visit next Friday to our water-works system in West Hartford, for, aside from the social character of your organization, there certainly is a more serious side, that being the coöperation given, individually and collectively, by this organization to one another in the furtherance of up-to-date systems of water conservation and distribution.

I am connected with the Board of Water Commissioners here for a period of only a very few weeks, and my experience here has impressed me with the fact that the citizens of Hartford know very little indeed about the magnitude of the work that has been carried on here during the last few years in the perfecting of their water system. It was my privilege in my early days to be a member of the Common Council of the City of Hartford, and during those days I witnessed the vicissitudes of Mr. Clark, the father of the Hon. Charles Hopkins Clark, whom we have with us here to-day, in his determination to not only install but to extend and maintain a system of water works for the city of Hartford. I have read of the work that the different boards of water commissioners have put through in order to secure proper legislative action to permit them to further the project now in hand, — the condemnation proceedings, the issuance of bonds, and, in fact. everything in connection with the work; but until I had an opportunity recently to go out and make a close inspection of our present system of water works I had no idea nor conception whatever of the magnitude of those works. You gentlemen no doubt will favor us by a visit out there this week, and we respectfully ask that you carefully inspect those works. The good things that you see about them you can carry back to your homes to advertise the system of the city of Hartford, and its defects you can make known to Mr. Saville.

None of us can fail to have been impressed in the last few years with the extensive work that has been carried on by federal, state, and municipal governments in order to solve the problem of pure food. Your vocation is far above this problem, for you are engaged in the conservation and delivery into the homes of the municipalities in the commonwealths which you serve God Almighty's health-giving, sustaining, and healing blessing, — pure water. Gentlemen, I thank you. [*Applause.*]

President Saville. Able journalist, independent in thought and speech, ardent and conscientious advocate of civic progress, indefatigable worker for public welfare, and efficient president of the Chamber of Commerce, — Mr. Frank G. Macomber.

ADDRESS OF WELCOME BY FRANK G. MACOMBER.

MR. MACOMBER. *Mr. President, Ladies and Gentlemen,* — When we were coming into the hall I suggested to your President that he had an aggregation that was sufficient to allow me to drop out, — that I appeared to be sort of an "also ran." He insisted that I was not, but in opening the meeting this afternoon I noted that he unconsciously agreed with me. He said that you had been honored by having gentlemen come here prominent in the city and the nation as jurists, in literature, in politics, and in business; and then he proceeded to introduce me as a journalist, which lets me out. [*Laughter.*] I can't class in any one of those.

This summer — in fact, only three weeks ago — I came to the very keen realization of how important is the work which you gentlemen do. I spent my vacation on Lake Keuka in the central part of New York State. Out there they say the lake is twenty-four miles long, three miles wide, and eight miles deep, and they have no water works. When I got up in the morning I used to chase down to the lake to get a pail of water, and I hadn't any more than got that pail of water up to the house than my wife would say that she wanted another one. I spent two very pleasant weeks carrying water from early morning until late at night, and from the amount of water I carried I distinctly question the figures which Mr. Clark gave here a few minutes ago as to the consumption of water in Hartford. He said that when there were not any meters the consumption was eighty-odd gallons of water per day per capita, and that since they have installed the meters it has dropped down to some sixty-odd gallons per day per capita. There were five of us in our family at the cottage, and I am very sure that I carried upwards of five hundred gallons of water a day. [*Laughter.*]

I also think that Mr. Clark in giving you those figures furnished a condemnation of your Association and all that it stands for. I was not in Hartford back in the days when there were no meters; in fact, I was a little too young, I believe, to know much about water in those days, but since I have come to Hartford I have found it necessary in the course of my business to examine from time to time the very interesting old files of the *Courant*, which Mr. Clark edits, and a very careful examination of the news

columns of those papers back in the early eighties demonstrates to my entire satisfaction that Hartford was not a clean town. [*Laughter.*] Yet they used eighty gallons of water per capita per day. Now we are only using sixty-six gallons of water, and it is a great deal better town than it was back when we put the meters in. We are going to demonstrate that to you during the next four days.

We who live here in Hartford — although I am only here with a twelve-year grip on it — we who live here in Hartford, as Mr. Clark and Mr. Gross have told you, are very proud of the city. They say we are very modest about it. We are not modest about it; we blow about it all the time, and we have a right to, and you are going to go away and say we have a right to. You have come to one of the most beautiful cities in the world, and you are going away and tell your friends that when we boast of Hartford we are modest in our boasting, but not modest about Hartford.

I come as the representative of the Chamber of Commerce, ladies and gentlemen, — a commercial body in the city numbering a thousand members, — and for each of those members I wish to give you a most hearty welcome. We want you to have a good time while you are in Hartford, as well as a profitable time, and we are going to do everything we know how to do to have both of these come true. I trust that, as the days go by while you are with us, if you notice anything that seems to be amiss you will call me up and let me know about it, and we will try to correct it right away.

I have said to other conventions that have met in Hartford, at which Mayor Hagarty has spoken, that he gives you the official welcome to this city and the official keys. I wish to say to you that, as a newspaper man and a modest follower in the footsteps of Mr. Clark, I extend to you through the Chamber of Commerce those other keys which you may need and which the mayor officially can't know anything about. [*Laughter and applause.*]

The President announced that the first business in order was the election of members. The Secretary read the following names of applicants for membership, all of whom had been approved by the Executive Committee:

Active — C. B. Crowell, Brattleboro, Vt., president and treasurer of the Brattleboro Water Works Company; Alexander Milne, St. Catharines, Ont., superintendent of water works; Harold W. Horne, Collinsville, Conn., division engineer for the Board of Water Commissioners of Hartford; Frank E. Howard, Hartford, Conn., president of Board of Water Commissioners of Hartford; Louis Treal, Lewiston, Me., superintendent Lewiston Water Works; Edwin T. McDowell, Middletown, Conn., superintendent Middletown Water Works; James H. Reynolds, Lowell, Mass., laboratory assistant and chief filter attendant, Lowell Boulevard Purification Plant; Arthur F. Shuey, Tampa, Fla., superintendent water works. — 8.

Associate — Henry N. Schramm, Philadelphia, Pa., contractor and water-works equipment; A. G. Lemoine, Montreal, P. Q., automatic sprinklers. — 2.

On motion of Mr. Lewis M. Bancroft, the Secretary was directed to cast one ballot in favor of the applicants, and, he having done so, they were declared elected members of the Association.

On motion of Mr. Robert J. Thomas, it was voted that the President appoint a nominating committee of five to name officers for the year 1918. The President subsequently appointed as members of the committee R. C. P. Coggeshall, George A. Stacy, William T. Sedgwick, Frank E. Hall, F. F. Forbes.

Adjourned.

Evening Session.

At the ball room of the Hartford Club a reception was tendered to the members of the Association and their guests by the Hartford Chamber of Commerce. Mr. H. Wales Dixon, Superintendent of Recreation, Park Commission, gave a description of the Hartford park system, illustrated by lantern slides. The lecture dealt particularly with the facilities for recreation afforded in the Hartford parks to both old and young. Dancing was enjoyed during the later hours. Refreshments were served.

Morning Session, Wednesday, September 12, 1917.

Vice-President Carleton E. Davis in the chair.

Mr. George A. Johnson, consulting engineer, New York City, read a paper entitled "Rapid Sand Filtration." Mr. R. S. Weston, consulting engineer, Boston, read a paper entitled "Mechanical Filter Bottoms and Strainer Systems."

These papers were discussed by Messrs. L. M. Hastings, R. E. Wise, Harold C. Stevens, William J. Willson, H. F. Dunham, Elbert E. Lockridge, and J. S. Dunwoody.

Mr. John W. Gaitenby, superintendent of filtration, Evansville, Ill., read a paper entitled "The Care and Operation of Rapid Sand Filters." The paper was discussed by Mr. Harold C. Stevens.

President Saville announced that Mr. F. L. Cady, of Providence, who was to have given a paper at this session entitled "Methods of Operation and Results Obtained with Slow Sand Filters," was unable to be present but that his paper had been received and would be read at a later session of the convention.

Mr. W. C. Hawley. We were very kindly entertained last evening by the Hartford Chamber of Commerce, and it is proper for us to express our appreciation. I move, therefore, that the Secretary of the Association be instructed to address a communication to the Hartford Chamber of Commerce expressing the appreciation of this Association of the courtesies of the Chamber of Commerce, and expressing also our thanks.

The motion was duly seconded and carried unanimously.

AWARD OF BRACKETT MEDAL.

Vice-President Davis. Before we adjourn, I should like to call upon Mr. Baker to make an announcement of the award of the Dexter Brackett Memorial Medal.

Mr. M. N. Baker. *Mr. Chairman and Members of the Association and Guests,* — I regret that Mr. FitzGerald, the chairman of the committee, is not present, — all the more so because it would have been especially fitting for him to make this announcement in view of his long-time association with Mr. Brackett. You will remember that a year or so ago a committee appointed

for the purpose of collecting a fund for the Dexter Brackett Memorial reported that such a fund had been collected, and recommended that a medal be awarded annually for the most meritorious paper that had been presented during the past year. This recommendation was approved and the basis for the awaid was fixed so that the award would be based on the consideration of the papers that had been published in the JOURNAL through the previous year. The award would, therefore, be for the best paper published in the JOURNAL in 1916. It is a great pleasure to announce — and it seems particularly fitting that it should have turned out to be such a happy coincidence — that the committee has unanimously decided that the most meritorious paper was that of your present President, Mr. Saville, entitled "Some Water-Works Experiences in Hartford, Conn.," which appeared in the JOURNAL for June, 1916. [*Great applause.*]

MR. CALEB MILLS SAVILLE. I do not think any remarks are necessary on that, except to say that I was very greatly surprised and very greatly pleased, and rather affected in a way. The Dexter Brackett in memory of whom the medal is given was the engineer of the distribution department in Boston during all the time I was there, — a ten-year period. Three other men — Mr. William E. Foss, now chief engineer of the Metropolitan Board of Supply; Mr. John L. Howard, the assistant chief engineer of the same board, and Mr. Alfred D. Flinn, the deputy chief engineer of the New York Water Supply — and myself as the fourth, were Mr. Brackett's principal assistants in laying out and constructing the distribution works on the Metropolitan System. Any good work that any of us four men have done since that time is due in large measure to our contact with Mr. Brackett, a man of the most sterling character, a man who was known — I don't need to tell the older members of this Association anything about him at all; but it is with the greatest appreciation that I receive this honor from the hands of the New England Water Works Association. [*Applause.*]

VICE-PRESIDENT DAVIS. I would like to say that the award has been approved by the Executive Committee and the medal will be presented at the November meeting.

Adjourned.

Afternoon Session.

President Saville in the chair.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Edwin L. Burnap, Norwich, Conn., superintendent Water Department; Theodore N. Kapoustine, Petrograd, Russia, special envoy from the mayor of Petrograd to study water supply conditions in the United States. — 2.

On motion of Mr. Lewis M. Bancroft, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared to be elected members of the Association.

Mr. Delos F. Wilcox, deputy commissioner Department of Water Supply, Gas, and Electricity, New York City, read a paper entitled "The Regulation of Private Water Companies in New York City." Mr. Hiram A. Miller and Mr. H. F. Dunham took part in the discussion.

Mr. Bertram Brewer, city engineer and superintendent of sewers and water works, Waltham, Mass., read a paper entitled "Water Rates Revision in Waltham, Mass."

Mr. Fred D. Berry read a paper entitled "Some Experiences with a Trenching Machine," written by Mr. George W. Batchelder, water commissioner, Worcester, Mass.

Mr. H. W. Hosford, water commissioner of Northampton, Mass., read a paper entitled "Water-Works Shop Construction." The paper was illustrated by stereopticon views.

Mr. A. E. Martin, who was to have read a paper at this session, entitled "Water-Works Shop Construction," explained that he had been unable to obtain slides to illustrate his lecture but that he hoped to be ready to give it at either the November or December meeting. He extended an invitation to the members of the Association to visit their shop in Springfield.

Adjourned.

Evening Session.

President Saville announced that Capt. Edward Canfield, Jr., U.S.A., who was expected to read a paper at this session, entitled

"The Organization for Building the United States Army Cantonment at Ayer, Mass.," was unable to be present.

Mr. H. R. Turner, superintendent of water works, Windsor, Conn., read a paper entitled "Some Operating Problems of a Small Works Department." The paper was discussed by Messrs. Frank L. Fuller, Frank E. Merrill, P. J. Conlon, and George A. Stacy.

Mr. William Haine of the Newlands Sanitary Laboratory read a paper entitled "The Control of Microscopic Organisms in Water Supply." Messrs. Wm. A. McKenzie, Frank L. Fuller, S. H. McKenzie, P. J. Conlon, W. C. Hawley, Harold K. Barrows, Walter H. Richards, and Homer R. Turner took part in the discussion.

Mr. Fred D. Berry read a paper entitled "Experiences with the Universal Cast-Iron Pipe," written by Mr. John H. Walsh, superintendent of water works, East Hartford, Conn. Messrs. Wm. J. Willson, S. H. McKenzie, Alfred D. Flinn, and others took part in the discussion.

Adjourned.

Morning Session, Thursday, September 13, 1917.

This session was given over to the reading of a number of papers on Hartford's water-works system, by members of the engineering staff, as follows:

"Past and Present Supply," by W. E. Johnson, division engineer; "The Distribution System," by Frank Brainard, assistant engineer; "The Engineering Work on the New Supply," by H. W. Horne, division engineer; "Features in the Design of the Spillway at Richards' Corner Dam," by R. E. Wise, designing engineer; "Construction of Masonry Dam on Nepaug River," by H. W. Griswold, assistant engineer; and "Grouting of Dam Foundations," by J. E. Garratt, office engineer.

Discussion regarding the above papers was participated in by Chester R. McFarland, L. M. Hastings, H. F. Dunham, Homer R. Turner, Frank L. Fuller, President Saville, Harold K. Barrows, and Hiram A. Miller.

Adjourned.

Afternoon Session.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Stephen Barden, West Springfield, Mass., for four years foreman in West Springfield; James H. Martin, West Springfield, Mass., foreman West Springfield Water Works.

On motion of Mr. Lewis M. Bancroft, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

Mr. J. L. Jackson, member of the Advisory Council of the Department of Health for the State of Connecticut, read a paper entitled "The Pollution of Streams in Connecticut." The paper was illustrated by steropticon views.

President Saville read a paper, illustrated by stereopticon views, entitled "Some Methods and Result of Filtration at Providence Water Works," written by Mr. Frank L. Cady, bacteriologist Providence Water Department, Providence, R. I.

Mr. S. E. Killam, superintendent pipe lines and reservoirs, Metropolitan Water Works, Boston, Mass., read a paper entitled "The Results of the Use of Meters in Metropolitan Water District, Boston." The paper was illustrated by stereopticon views. Messrs. Frank L. Fuller, W. A. McKenzie, F. H. McKenzie, Frank E. Merrill, President Saville, E. S. Cole, W. C. Hawley, Wm. J. Willson, and H. F. Dunham took part in the discussion.

Adjourned.

Evening Session.

President Saville. The first business will be the presentation of the report of the Committee on the Consumption of Water, — Mr. Edward S. Cole, of New York.

Mr. Edward S. Cole. *Mr. President and Gentlemen of the Association,* — As a preface, I might say that the work of this committee has been an attempt to segregate the uses of water so that the reported figures of per capita consumption for various cities might be compared more fairly and legitimately. For many years we have had only the total per capita use of water available. It was only on this basis that we have had to compare

one city's performance with another. And it was in order to produce a standard which would be a more reasonable basis of comparison that an effort was made through committee work to segregate the uses, and based upon meter readings. This committee has its final report to make in that connection.

(Mr. Cole then read the report of the Joint Committee on Water Consumption, New England Water Works Association, 1917.)

On motion of Mr. Frank L. Fuller, duly seconded, the report of the committee was accepted and adopted.

WAR-TIME CONSTRUCTION OF PUBLIC WORKS.

President Saville. I am going to ask Mr. Richards to say a few words on municipal improvement, municipal work, and its relation to conditions at the present time.

Mr. Walter H. Richards. *Mr. President and Gentlemen,* — What I have to say is a very few words. It won't take long to deliver my message, but it appears to me to be quite an important one. That is, what is the position of this Association in the matter? In a recent editorial in a paper devoted to advertising construction work and tools, the endeavor is made to prove that it is desirable to proceed with municipal construction work regardless of abnormal costs and abnormal conditions; indeed, the existence of these conditions is denied. These conditions are well known to any member of this Association who has undertaken construction work during the past year, whether by contract or by day labor, so that it is only necessary to state them briefly.

A large proportion of the day labor of this country is done by aliens or near aliens, a large portion of whom have now left this country to fight the battles of their own countries. Naturally they are the most efficient ones who have gone. Thus, while the cost of labor, due to scarcity, has advanced about 40 per cent., the efficiency has declined until the actual value of labor has been reduced at least 50 per cent., and this condition is likely to be exaggerated by the demand for men for our own armies.

The materials and tools which are required for construction have increased from two to three times in cost over that of years ago. It is, then, safe to say that the cost of any new construction has doubled in two years and is now double the normal or real value.

Whether construction at this time is paid for at once or by bonds or securities to be paid by posterity, the investment is twice its normal value. Would any careful business man make an investment without knowing that the future receipts would warrant the expenditure? It would seem that all new work except that immediately demanded for the preservation of life and health should be deferred until normal conditions are restored, for economic reasons.

But there is another reason: This country is at war, — your country, my country, is in jeopardy. Every dollar, every bit of energy, all the skill and efficiency should be devoted to saving it from destruction, and until that is accomplished nothing else matters. If a camp needs a water supply, build it and charge it up to profit and loss; but do not build anything that can be deferred until the future.

Many of the members of this Association are too old to carry a gun. Some of us could not tote a fifty-pound pack a half a mile, but, in the words of a distinguished member of this Association, "If we can't fight the Huns, we can hold the fort." [*Applause.*]

Mr. Henry R. Buck. This seems to me a most excellent idea, and one which the Association would do well to second at this time on economic grounds alone. We know that the cities can do the most good by furnishing work to the unemployed when there is a large number of unemployed. Here in Hartford, during the panic of 1893, work was found, that did not need to be done, to keep people busy, and economists tell us that we may expect another period of depression after the war. On that economic ground alone it seems to me worth while to defer every bit of unnecessary construction during these abnormal times. But the patriotic reason is, of course, so much stronger that that should take precedence over any mere economic reason. I understand that in England new construction of all sorts is absolutely forbidden. New residences are forbidden to be built except where absolutely necessary. It may come to that point in this country. Where we engineers can do so, I think we might very properly postpone any new projects.

President Saville. Did you put it in the form of a motion?

Mr. Richards. No, I did not. I move that it is the sense

of this Association that any public work, except that necessary for life and health, be deferred until conditions change.

The motion was duly seconded.

Mr. A. Prescott Folwell. I agree with what Mr. Richards said, and I should like to supplement it with a little idea of my own — a little additional idea. We want to be careful in judging what we mean by work which is immediately necessary. No one knows how long this war is going to last, — whether it is going to last six weeks or six years; but the probability is that for a short time after the discontinuance of the war, materials will still remain high, because there will be an unusual demand for them. As to the labor, that is, of course, another matter. But let us assume that the war will last for one year longer. During that time, within the next six months possibly, the United States will call for an additional number of men to join the army. That will mean that labor will become still more scarce. The price of material will not fall in the mean time; everything will rise. Consequently, it seems to me when we are trying to judge of what is immediately necessary, which we should endeavor to put through, we should consider as immediate anything which may be needed within the next year at least, — possibly two years, but let us say one year. Any work which is going to be needed within the next year, it seems to me, for economic and patriotic reasons both, should be put through as soon as possible because six months from now we will probably find both labor and material more scarce than they are at present.

The motion was unanimously carried.

Mr. George A. Stacy. Mr. President, I think at this time it is well to give the Association an opportunity to express its gratitude to the city of Hartford and its citizens for the courtesy that has been showered upon us, the hearty welcome we have received here, so that it may go upon the record. The weather has been magnificent, and that is typical of the conventions which we have held here. And I suppose that is due to the prayers and good-will of the citizens of Hartford, for which we are very thankful. And in order to put it in some kind of form and to put on record the feelings of the New England Water Works Association for the privilege of holding this convention here, the reception and the

courtesies which have been tendered us, I move that a vote of thanks be given to his Honor the Mayor; to the Hon. Charles Hopkins Clark, the editor of the Hartford *Courant;* to the Hon. Charles E. Gross, of the firm of Gross, Hyde & Shipman; to Mr. Frank G. Macomber, President of the Hartford Chamber of Commerce; and to those ladies who have so nobly and so well entertained our better halves and kept them satisfied, entertained, and happy, of whom Mrs. Frank G. Macomber is the chairman, assisted by a very able corps of ladies of the city of Hartford. We go away from here with new thoughts, with new ideas, and much to think of in the future. In the closing of this convention, as it is coming to a close, it is fitting that we should express this. Mr. Chairman, I move that a hearty vote of thanks be extended to these people I have mentioned, and many others I can't call to mind, for the courtesies, the hearty welcome, and the many kindnesses they have extended to us while we have been in this splendid city.

The motion was seconded.

Mr. Stacy. Excuse me; I made a serious blunder. I have not included the all-inclusive, — the Board of Water Commissioners of the City of Hartford, for which we have the deepest respect.

The motion was unanimously carried by a rising vote.

President Saville. Before proceeding to the regular reports of the committees, or beginning with the regular reports, perhaps I will call on Mr. Woodburn for the report of his Committee on Exhibits of the associated members during this convention.

Mr. Wm. Woodburn. I am sorry to say that on account of a number of little matters that came up late this afternoon we have not been able to get our report in shape, but I will have it ready so that it will be presented to you at the November meeting.

President Saville. I think we are now ready to proceed with the regular reports of committees. Mr. Hawley, is your committee ready to report?

Mr. W. C. Hawley. (Committee on Revenue from Fire Service.) We had a meeting on Monday of four of the members of the committee, but unfortunately none of those representing the insurance interests were there. I think that there is no serious difference between the water-works men on the committee and

those who represent the insurance interests, and I hope that we shall be able to present a report which shall be satisfactory and which will agree in principle, at any rate, with the reports of the American Water Works Association and the National Fire Protection Association.

In this connection I want to call the attention of the members of the convention very briefly to the Portland water decision. There are two or three things in that decision which are very interesting and which I think are going to be very helpful in the solution of the problem.

On motion of Mr. S. E. Killam, the report of progress of the committee was accepted, and the committee continued.

On motion of Mr. S. E. Killam the courtesy of the floor was extended to non-members during the discussion of topical matters.

There was a general discussion on the subject of water pipes for mains and services, participated in by Mr. Barker, of the Lock Joint Pipe Company; Mr. S. H. McKenzie, Mr. James E. Flinn, Mr. Henry R. Buck, Mr. F. N. Speller, and Mr. Carstein, of New York.

Adjourned.

Friday, September 14, 1917.

The day was devoted to an excursion to the sources of supply of the Hartford Water Works, by invitation of the Hartford Watei Board.

EXECUTIVE COMMITTEE.

Meeting of the New England Water Works Association at Unity Hall, Hartford, Conn., at 1 o'clock P.M., Tuesday, September 11, 1917.

Present: President Caleb M. Saville, and members Carleton E. Davis, Samuel E. Killam, Frank J. Gifford, A. R. Hathaway, William S. Johnson, and Willard Kent.

Eight applications for active and two for associate membership were received and unanimously recommended therefor, viz.,

For Active: Louis Treal, superintendent water works, Lewiston, Me.; C. B. Crowell, general manager, Brattleboro Water Works Company, Brattleboro, Vt.; James H. Reynolds, laboratory assistant Lowell Boulevard Purification Plant, Lowell, Mass.; Edwin T. McDowell, superintendent water works, Middletown, Conn.; Frank E. Howard, president Board of Water Commissioners, Hartford, Conn.; Harold W. Horne, Collinsville, Conn.; Arthur F. Shuey, superintendent water works, Tampa, Fla.; Alexander Milne, engineer and superintendent water works, St. Catharines, Ont.

For Associate: Chris D. Schramm & Son, Philadelphia, Pa., and A. G. Lemoine, Montreal, Canada.

The following report of the Committee on Award of the Dexter Brackett Memorial Medal for the year 1916 was presented:

Report of the Committee to Recommend Award of the Dexter Brackett Medal.

The undersigned, a committee appointed by the New England Water Works Association to award the Brackett Medal for 1916, respectfully present the following report:

The principal condition governing the award of the Brackett Medal is as follows: "The medal shall be awarded for the paper which is judged to be most meritorious, bearing in mind its applicability to general water-works problems."

Bearing in mind the above condition, we recommend the award of the medal

to Caleb Mills Saville, for the paper entitled "Some Water-Works Experiences in Hartford, Connecticut"

DESMOND FITZGERALD, *Chairman,*
M N BAKER,
A. E. MARTIN,
Committee.

JULY 23, 1917.

And in accordance with their recommendation, the award was by unanimous vote made to Caleb Mills Saville, of Hartford, Conn.

Adjourned.

Attest:

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Unity Hall, Hartford, Conn., at 7.30 P.M., Thursday, September 13, 1917.

Present: President Caleb Mills Saville, and members Samuel E. Killam, Percy R. Sanders, William S. Johnson, Lewis M. Bancroft, and Willard Kent.

Four applications for membership were received and by unanimous vote recommended therefor, viz., Edwin L. Burnap, superintendent water works, Norwich, Conn.; Theodore N. Kapoustine, district engineer, Municipal Water-Works Department, Petrograd, Russia; Stephen Barden, foreman water works, West Springfield, Mass.; James H. Martin, foreman water works, West Springfield, Mass.

The Committee of Arrangements report the conditions under which the Manufacturers Association contributed to the expenses of the present convention as follows:

1. That none of their members, list of which is enclosed herewith, be requested for any contribution towards the entertainment fund;

2. That the Chairman of Exhibit Committee should be selected from among their members;

3. That the additional $5 charged Associate members for all representatives attending the convention in excess of one shall

be turned over to the Chairman of the Exhibit Committee to defray exhibit expense;

4. That the expenses of the Exhibit Committee will be distributed among the exhibitors in proportion to the square feet of space occupied by their exhibits;

whereupon it was voted: That the action of the Committee of Arrangements in relation to the present convention be approved without recommendation for future action.

Adjourned.

Attest:

WILLARD KENT, *Secretary.*

New England Water Works Association.
ORGANIZED 1882.

Vol. XXXI. December, 1917. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

PRESIDENT'S ADDRESS AT ANNUAL CONVENTION, SEPTEMBER 10, 1917.

Gentlemen of the New England Water Works Association, — You have heard the speakers who have preceded and you have listened to the greeting that Hartford extends to the New England Water Works Association.

A very able diplomat is alleged to have stated that "language was given man to conceal thought." From my personal and official contact with these gentlemen and those whom they represent, I can assure you that Talleyrand's thought does not apply to the people of Hartford.

Gentlemen of the city of Hartford, in the name of the New England Water Works Association it gives me the greatest pleasure to thank you for your kind words, for the cordial welcome you have extended, and for the hospitality which you have indicated to be your purpose to show us during our stay in Hartford.

In starting out on our convention program, a few words may not be amiss as to the aims and objects leading up to this meeting.

The New England Water Works Association is a "get-together" organization of men whose principal business is connected with supplying water. Included in our membership are specialists in various matters of water supply, water-works operators who are doing the practical, every-day work, and manufacturers of water-works equipment who provide the materials we use in our work. Each of us is here to help the other and by so doing help the public whom we serve. Men from all parts of the world are on the rolls

of this Association, and to those who know its beginnings and its traditions there is a very deep personal interest in its life and future.

The matter of supplying water is of a different character from that of any other municipal industry. All others primarily are disbursing agencies handling allotted funds. Their principal duties are to see that their funds are honestly and economically expended on predetermined work.

The water department, on the other hand, is always a commercial enterprise, similar in many of its requirements to other public utilities, as, for example, the business of furnishing light and power by gas or electricity and the running of steam and electric railways. Here there is a question both of production and distribution, with new problems continually arising as to methods of operation and maintenance. Economical and efficient means must be employed to produce an article that will satisfy customers and be delivered to them at fair rates. The plant must be operated in such a manner as to be at least self-supporting. Thousands of consumers must be handled individually with the same regard as obtains in the best conducted retail trade. The demands of a modern water-supply system are complex and are concerned with matters little dreamed of a generation ago.

The men who are efficiently handling this work to-day are trained, practical men, skilled in their professional work, single-eyed to economical administration, and alert to recognize, seize, and apply the latest developments in water-works science.

To-day something more is required of the water-works executive than to be able to get four hundred eighty minutes' work for the price of labor, properly to lay pipe, and quickly to repair a break in a supply main. These things are necessary in carrying on department work, but they are not the essentials of present-day management. The water-works executive must be familiar with all of these, but in addition he must have intimate knowledge of and ability to handle such financial questions as valuation of works and equitable rate making, as well as hydraulic problems relating to supply and construction or the complex questions involved in providing a water which satisfies modern standards.

Intelligent systems of accounting are necessary. Rules and regulations adjusted to present conditions are required. Scientific purchase of materials and supplies, cost keeping that instructs, modern transportation, checks on the care of department property, and similar matters, are all part of the organization of even the mediocre construction company. How can water department business succeed without them? The question of revision of rates to meet existing conditions is most vital to successful operation, but one which is often the last to be taken up, particularly in municipally operated plants.

Many rate schedules now in use even in our larger cities are inheritances of the past, continued because of the inertia of the present. Some of these are ridiculously inadequate and fail utterly to recognize conditions of plant, cost of operation, and special value to different classes of users. Such conditions result in extravagant operation and in ineffectual service.

At the present time it is the trend of opinion, based on judgment of the best sanitary specialists, that all public water supplies sooner or later must be filtered. Water is demanded which is clean and attractive as well as that which is safe. These questions involve protection from pollution, removal of turbidity and color, reduction of chemical constituents producing hardness and other detrimental conditions, and the elimination of taste and odor.

These are some of the problems of the modern water-works executive. Properly met, they mean efficiency in organization and economy in operation, with consequent benefit to the city. To do these things it is necessary that the manager of the water department shall be able to grasp, understand, and control adverse conditions which were formerly accepted as inevitable but are now known to be amenable to remedy if not to cure.

The past experience of this Association with its avoidance of entangling alliances is the best guide we can have for the future. Our present position as a power in water-department matters shows clearly the wisdom of the founders of this Association in rigidly excluding both politics and commercial exploitation from its voting membership. "As with the fathers, so may God be with us."

With other organizations we will work together gladly, and we welcome all water-works men to our membership.

Careful consideration of our own particular needs and purposes, however, forbids any thought of combination with others.

In these critical and serious times it is well for us to cultivate the attitude of the open mind and the spirit of coöperation.

One of the most cogent reasons why our manufactured products, up to the war period, had so little market in Central and South America was the arbitrary stand of American producers as to details of construction and methods of packing goods, regardless of the needs of the purchaser.

Until many of our manufacturers and consumers, on the one hand, emerge from this attitude of pigheadedness, and on the other step aside from a position of cocksureness, there will be difficulty in meeting the demands of commercial enterprise and construction possibility. Opportunity is hindered by ignorance and the effect of the small mind, unable to comprehend the standpoint of the other fellow. The talisman of success is "coöperation." Manufacturers must concede the necessity and be willing to consider with open mind changes in plant, even though expensive to them, if efficiency and economy result in construction work.

Engineers and users of manufactured products must recognize business exigencies and matters affecting established industry. They too must have the open mind which is free from personal bias, broad in its outlook, and dispossessed of a finicky attitude. In the "get-together" atmosphere of this convention let us all try to get into touch with the real reasons for the differences between users and producers and see if we cannot reach some mutually advantageous ground in advance of that on which we now stand.

In these days the direction of the force of gravity as regards cost of labor and materials appears to have been reversed. An efficient way, and perhaps the best way, to meet this condition seems now to be the more general use of labor-saving tools, careful selection of materials, more thoughtful planning of work, and better organization of force. Present prices of labor and materials in many cases are beyond that ever before experienced, and the outlook into the future seems to reveal little or no downward

tendency. For a short period there seemed to be a faltering in construction work, but contract news, construction advertisements, and bond sales indicate recovery, with a tendency to accept present prices as better perhaps than will be afforded later. From this viewpoint, more and more public work of considerable magnitude is being let. With the reduction of labor due to national requirements and the possibility of greater demands for materials, even if peace should come quickly, there seems to be greater chance for increasing cost of work for some time to come.

To consider these problems, gentlemen, is the reason we are in convention at Hartford this week. While we sincerely appreciate and shall heartily partake of all the hospitality and the entertainments offered, business, more perhaps than ever before, should take precedence. For this purpose we are to listen to papers presented by sanitary engineers skilled in special lines, by practical water-works operators who are doing things worth while on their own water-works departments, and by makers of appurtenances used and necessary in water-department work. Valuable as are these papers, more useful yet is the discussion which should arise. Special practical problems are welcomed for solution, for questions that perplex one are sure also to have troubled many others.

Gentlemen, the convention is now open. Gain what you can from the store of instruction which is yours for the taking, and enjoy to the utmost Hartford's bountiful hospitality.

THE REGULATION OF PRIVATE WATER COMPANIES IN NEW YORK CITY.

BY DELOS F. WILCOX, PH.D., DEPUTY COMMISSIONER OF WATER SUPPLY, GAS, AND ELECTRICITY, CITY OF NEW YORK.

[*An address before the New England Water Works Association, at Hartford, Conn., September 12, 1917.*]

New York City claims the distinction of having the largest municipal water plant in the world. It has already invested $360 000 000 in water works, and is still going on with the development of its supply. It now furnishes water at the rate of about 550 000 000 gallons per day to a population of over 5 000 000 people and has a total dependable supply of between 700 000 000 and 800 000 000 gallons per day. Although it is an "unmetered town," and although the commissioner of water supply has thus far been unable to secure the legal authority to require the installation of meters in residential premises, nevertheless there were, on June 30, 1917, 104 357 meters in service. I suppose that New York City's municipal water works constitute the largest experiment in municipal ownership and operation existing anywhere in the world.

The magnitude of the problems growing out of the construction and operation of this water plant has had the effect of distracting attention from the operations of the private water companies still serving portions of the metropolis, and of obscuring their relations to the city government. The fact is that five important water companies that enjoy public franchises are still operating within the limits of Greater New York. Indeed, about one fourth of the city's area, and 400 000 of its population, are at the present time dependent directly upon the private companies for both domestic service and public fire protection. Besides the five larger companies which are operating in their respective territories without any appreciable competition from the municipal water plant, another company of considerable magnitude, operating under easements obtained before the streets were opened to

the public, is serving a considerable population in direct competition with the city plant, and still another company, operating under a public franchise, offers a small but annoying problem of competition to one of the larger companies. An area of 85 square miles and a population of 400 000 would, in most localities, constitute a large city, and the water problem of such a city would be very much more complicated than that of most cities if, instead of being served by a single plant, it was served by seven different plants owned and operated independently of each other.

In the city of New York the Department of Water Supply, Gas, and Electricity combines, under the jurisdiction of a single commissioner, the operation of the municipal water works; the supervision of the private water companies; the provision of street and public building lighting through contracts with private corporations; the control of the subsurface structures of gas, electrical, telephone, and steam heating companies; electrical inspection, and certain minor functions of municipal government. For the purposes of this paper we may neglect all of these miscellaneous functions which do not have a direct relation to the water service. It is necessary, however, to describe in brief outline what the commissioner's powers are in relation to the municipal water works in order to give the proper perspective to the problems arising out of his exercise of supervisory control over the private water companies.

The major portions of the municipal water-works plant, other than the distribution system, have been constructed from time to time by separate agencies such as the Croton Aqueduct Board and the Board of Water Supply, but the commissioner's jurisdiction over all water-works structures when they come into use as a part of the municipal plant is complete. It is also his duty to look out for the city's needs and select new sources of water supply, which, with the approval of the Board of Estimate and Apportionment and the Board of Aldermen, may be taken by condemnation proceedings anywhere within the state of New York, provided they are not already in use, or reasonably necessary for the future use of some other municipality. The commissioner also has jurisdiction over the construction and extension of the distribution system and pumping stations and other local facilities in

connection with the operation and development of the water plant. The money for all construction work is obtained through the issuance of municipal bonds, and the comissioner is powerless to use the revenues derived from the sale of water for extensions to the distribution system. Thus his discretion in construction matters is strictly limited by the financial control exercised by the Board of Estimate and Apportionment, whose approval is necessary for the issuance of bonds for water purposes.

In respect to the relations of the water department to the consumers, the commissioner's powers are described and limited by the provisions of the Greater New York charter and the code of ordinances. In the establishment of rates and charges, his action is subject to approval by the Board of Aldermen, but the water rents, based upon the rates and charges so fixed, are, by charter, made a lien upon the premises where the water is supplied, and the times for the payment of water rents and the penalties imposed for failure to pay promptly are also fixed by the charter. The commissioner is authorized, in his discretion, to cause water meters to be installed in all places where water is furnished for business consumption, but he has no power to require their installation in residential premises unless authorized to do so by the Board of Aldermen. Individual property owners, however, may at will demand the installation of meters on their services, whether the water is used for domestic or for business purposes. The commissioner has a wide latitude in the establishment of rules and regulations for the control and operation of the municipal water works, but, of course, such rules and regulations must fall within the limitations laid down by the charter and the ordinances. In practice, New York City requires the consumer to install and maintain the service pipe, and also the meter wherever the use of the latter is authorized. Theoretically, the commissioner can establish rules by which the purchase, installation, and maintenance of meters and service pipes would be assumed as a department function, but under existing restrictions of law and ordinance the expense in both cases would have to be charged against the property owners. Moreover, the commissioner's financial restrictions are such that it may at times be impracticable for him to make a radical change in the procedure of the water

department in matters of this sort without having secured in advance from the financial authorities of the city the appropriations necessary to carry them out. The revenues from the sale of water are not available for use by the commissioner in the operation of the department except to the extent that specific provision has been made therefor in the appropriations.

I refer to these matters for the purpose of showing the limitations imposed by legal and financial conditions upon the commissioner's discretion in regard to the operation of the municipal water plant, as contrasted with the absence of such limitations upon his control over the operations of the private water companies now to be described.

Private water companies in the state of New York are organized under the transportation corporations law, and, in the absence of special charter provisions governing the granting of franchises, they have usually secured perpetual rights by the simple process of applying in advance to the local authorities for permission to organize for the purpose of supplying the community with pure and wholesome water. Neither private water companies nor municipal water plants have thus far been brought under the jurisdiction of the public service commissions of the state, and thus no general machinery has been provided for the control of their rates and service. They are subject to the State Health Department in matters relating to pollution and to the State Conservation Commission with respect to the acquisition and development of additional supplies.

Within the limits of Greater New York the absence of effective state control over the rates and practices of these companies is made up for, in part, by a provision of the charter giving to the commissioner having charge of the municipal water works, power over the operations of the private companies, of which the municipal plant is a potential or, it may be, an actual competitor. Section 472 of the charter authorizes the commissioner " to examine into the sources of water supply of any private companies supplying the city of New York or any portion thereof or its inhabitants with water to see that the same is wholesome and that the supply is adequate, and to establish such rules and regulations in respect thereof as are reasonable and necessary for the convenience of the

public and the citizens." It also provides that the commissioner "may exercise superintendence, regulation, and control in respect of the supply of water by such water companies, including rates, fares, and charges to be made therefor, except that such rates, fares, and charges shall not, without the consent of the grantee, be reduced by the said commissioner beyond what is just and reasonable." It is further provided that "in case of a controversy, the question of what is just and reasonable shall be finally determined as a judicial question on its merits by a court of competent jurisdiction."

This is the public service law applied to private water companies in the city of New York. The use of the word "fares" with relation to the charges of a water company suggests that this provision of the law was "lifted" from some other statute, which had relation to street railway companies. Perhaps the astute legislators figured that inasmuch as a water company has to be incorporated under the transportation corporations law, it could with entire propriety charge "fares" for its water. The use of the word "grantee" in the provision relating to the company's acceptance of a regulation of rates promulgated by the commissioner also bears the earmarks of extraneous origin. This word seems to connote a condition applicable where rates are being fixed in connection with the granting of a franchise, although the commissioner has no franchise-granting powers whatever.

In addition to the verbal peculiarities just noted, this regulatory law presents a number of rather unique features. In the first place, it is very broad and general in its language, keeping as far as possible away from the minute and involved details incorporated in the public service commissions law of New York, and in similar laws of other states. This has the result of leaving both the commissioner and the companies in the dark as to the precise extent of his jurisdiction over them, and in the absence, during a period of nearly twenty years, of any serious litigation affecting the commissioner's powers, they have remained in a happy condition of uncertainty. We sometimes read that operations on the European battlefront are temporarily suspended on account of fog. I should not care to be called upon to guess whether the continued fog enveloping the commissioner's authority over the

private water companies was responsible for the absence of more active operations on this particular war-front during the sixteen years prior to 1914, or whether the spirit of coöperation between the water department and the private companies during this period was so cordial that the presence of the fog was in no way embarrassing to them. Only recently, litigation has been started to test the commissioner's right to compel the private companies to install water main extensions. In this case the company "took first blood," as the judge in the lower court held that the broad, general language of the statute does not give the commissioner authority to require a private company to extend its mains. The case is being appealed, and it is hoped that through the smooth-moving processes of adjudication the commissioner's powers with respect to extensions will ultimately be defined and established upon a solid foundation.

[The decision of the lower court has just been reversed (December 8, 1917) by the Appellate Division, in an opinion fully sustaining the commissioner's authority to require a private water company to extend its distributing mains.]

The second point of interest in our regulatory law is the absence of any limitation upon the commissioner's powers with respect to the fixing of absolute as distinguished from maximum rates. Under the public service commissions law of New York, the rates fixed by public authority are maximum rates, while in Wisconsin, California, and some other jurisdictions the commissions have been given specific authority to fix absolute rates. It is of considerable importance to the commissioner that his control over the charges of the private water companies should be such as to enable him to fix absolute rates, especially in view of the existence of competitive conditions with respect to the water service in certain areas. It is clear that under conditions of actual or potential competition the power to fix absolute rates is an essential factor in effective regulation. The commissioner's authority in respect to this matter has never been tested in court.

The third point of interest in our regulatory law is the provision that the commissioner shall not *reduce* the rates of the private companies beyond what is just and reasonable without their consent. Apparently, the authors of the law did not antici-

pate that the commissioner would encounter any serious objections from the companies if he attempted to raise their rates, and it was not considered necessary in the days when this law was drafted to provide the aggrieved consumers with any specific means of relief in such a contingency. Another issue has arisen in this connection because of the fact that the city as a municipal corporation, within the areas which the companies serve, takes water from them for street uses, for the supply of public buildings, and for fire protection. It has been the policy of the city up to the past few years to enter into contracts with the several companies for hydrant service. All such contracts, under another provision of the charter, before being executed by the commissioner, must be approved in all their details by the Board of Estimate and Apportionment and also by the mayor and the comptroller separately. Upon the expiration, a number of years ago, of the hydrant rental contracts between the city and the Queens County Water Company, it was found impossible to negotiate terms for hydrant service under a new contract acceptable to both parties, and, therefore, as the hydrant service was absolutely necessary, the company continued to render it and the city continued to pay for it without any contract. Ultimately, when the question of the revision of this company's rates to domestic consumers came before the commissioner, he found that the city was paying much less than the fair cost of the fire protection service, while the rates to private consumers were too high. The question then arose as to his power to increase the hydrant rates payable by the city, without the consent of the Board of Estimate and Apportionment or any other city authority. The commissioner was advised by the corporation counsel that his power to regulate the rates of a private water company extended not only to rates for domestic and business service, but also to rates for hydrant service and public fire protection. Acting upon this advice, the commissioner assumed the full responsibility of readjusting the rates, in the particular case to which I refer, in such a way that the financial obligations of the city, so long as it continued to accept the service from the company, would be largely increased, while the rates to domestic consumers were reduced. The company promptly accepted the rate order, but it was some

time before the Board of Estimate and Apportionment and the comptroller, constituting the financial authorities of the city, concluded to accept the new rates. The curious thing about the legal situation in this case was that the city as a consumer had no practical method of appealing from the decision of the Commissioner of Water Supply, Gas, and Electricity acting in his capacity as an impartial regulator of water rates.

Still another point of interest in our regulatory law is the provision as to what shall happen in case of a controversy between a company and the commissioner over a proposed reduction of rates. The statute provides that in such a case the question as to what are just and reasonable rates shall be finally determined as a judicial question on its merits by a court of competent jurisdiction. While the procedure to be followed under this provision of the law has never been worked out in practice because of the fact that no litigation between the city and a private company has yet been undertaken in respect to the regulation of a company's rates, it appears from the language used that when the commissioner has rendered his decision, if the company affected refuses to accept it, the commissioner's order will be ineffective, and just and reasonable rates will not be fixed at all by public authority unless, by injunction proceedings or otherwise, either the city, or the company, or the consumers, remove the whole question to the courts, where the issue will be treated as an original one, no matter what kind of a record has been made before the commissioner. Moreover, it appears that the decision of the court, technically at least, will not be to sustain the commissioner's order, or, in case the order is found to be unjust and unreasonable, to reverse it and refer the question back to the commissioner for further consideration, but, on the contrary, the court will have to assume the responsibility of fixing the rates on the basis of evidence produced before it. This is another point of great importance that, in the absence of litigation to determine it, rests upon the insecure foundation of interpretation of law by laymen, whose judgment is often warped by the assumption that statutes, when apparently clear, mean what they say.

The exercise of the commissioner's powers of control over the private water companies is affected, equitably if not legally, by

the fact that it is the general policy of the city of New York to extend the municipal water service throughout its boundaries and to attain, so far and so soon as practicable, a monopoly of the public water service.

In view of the enormous investments which the city has made in its water works and of the general tendency toward the municipalization of public water service, it is somewhat surprising that the private water companies operating within the city limits have not been entirely eliminated long ago. These companies got their start, not in franchises granted by the present city or by the former city of Brooklyn, but in franchises granted by numerous towns and villages which were subsequently brought into the Greater City. No water franchise has been granted within the present limits of Greater New York during the past twenty years. The city has already acquired a number of private water companies, notably those which formerly operated on Staten Island, until now the operations of the private companies are practically confined to three of the five wards of the borough of Queens and two of the thirty-two wards of the borough of Brooklyn. The city's progress towards the extinguishment of these companies has no doubt been retarded in the past by the continued shortage of water available for the supply of Brooklyn and Queens, these boroughs constituting the portions of the Greater City which occupy the western end of Long Island. Indeed, this shortage was so great that for many years the city purchased large quantities of water from the company operating in the second ward of Queens for delivery into the municipal mains for distribution to the city's consumers in the first ward of that borough. All the private companies on Long Island derive their supplies from wells, and it is a physical characteristic of Long Island that a water supply can be secured from the ground in almost any location by means of an adequate well development. Local supplies for the service of restricted areas can be economically developed in comparatively small units on Long Island, and a private water company in a suitable location may be able to supply the section of the city in which it operates at a lower cost per unit than the cost to the city of developing a supply adequate for a much larger service. Pending the completion of the city's great project for

bringing an abundant supply from the Catskills, it was not altogether uneconomical, from the water supply point of view, to permit the several private companies on Long Island to continue in operation in those districts where the city had no mains. Moreover, it must be admitted in fairness to the existing companies that, as a general thing, their consumers seem to be well satisfied with the quality of the water supplied, particularly for drinking purposes, and it is not strange that people who have been accustomed to the relatively hard and cold waters supplied from the wells of Long Island should be somewhat hesitant about taking in exchange the soft surface waters from the Croton and Catskill watersheds which constitute the city's principal sources of supply.

Nevertheless, the continuous encroachment of population upon the watersheds of the companies results in a gradual lessening of the amount of water available from these sources, while at the same time the increased demand for it tends to cause an overdraft upon the wells, with a resultant increase in chlorine and hardness which makes the water less desirable, particularly for industrial and laundry purposes. Also, the possibility of pollution as the growing city flows out to encompass these water-bearing lands tends to weaken the consumer's predilection for his local supply as compared with the supply from the mountains which the city now offers. All of these factors tend to complicate the relations existing between the commissioner as a regulatory authority and the private companies.

The city is now in a position where it has surplus water to sell, and would be glad to extend its service without further delay to the areas now served by the private companies. It would be glad to purchase their distribution systems and incorporate them as a permanent part of the municipal water plant, but unfortunately a large portion of the properties of these companies consists of lands, wells, pumping machinery, and buildings which, if acquired by the city, would be of no appreciable use to it for water purposes. The city has no desire to destroy the companies' legitimate investments, and for that reason prefers not to enter the territories served by them and parallel their mains for the purpose of competing with them. But the city takes the position that its enormous expenditures for the purpose of introducing an abundant

supply of water into the metropolitan area have actually and properly had the effect of depreciating the value of the companies' plants taken as a whole, by rendering portions of them obsolete or nearly so. At the same time, the city is unwilling to permit the companies to continue to operate their private plants without regard to the demand for uniformity of rates and conditions of service throughout the city area. Some of the companies charge rates considerably higher than the city rates, and most of them tend to be much more conservative than the city would be in the layout of their distribution systems and in the quality of the fire protection rendered to the districts in which they operate. The city does not wish to disregard what it considers to be their legitimate rights, but at the same time it is unwilling to limit for their benefit its policy as to water rates and as to the development of the water service throughout the metropolitan area. In the case of some of the companies, their land holdings are an important element of their property, and it is with reference to this factor particularly that the city is unwilling to compensate them on the basis of an assumed monopoly value for sources of water supply which the city does not need.

In view of the conditions which I have outlined, the efforts of the water department during the last three or four years have been gradually quickened with respect to the supervision and regulation of these companies. The principal lines along which regulation is now being undertaken are the following:

1. The department's first duty in relation to the private water companies is to supplement the functions of the state health department and the local board of health with respect to the quality of the water supplied for domestic uses. The department maintains a laboratory at which its own water supply is subjected to continual examination as to its chemical and bacteriological contents. In like manner, samples are taken monthly from the different pumping stations of the several private companies and subjected to careful scrutiny. Whenever such examinations show indications of possible pollution, the companies are notified and special investigations are made to find out what the trouble is. These laboratory tests are also used for the purpose of determining the quality of the water with relation to such matters

as its iron content, its hardness, or the presence of obnoxious gases tending to impair its potability. In this way the department performs for the private water companies and for their consumers a fundamental service by the insistence upon high standards in relation to the purity and potability of the water supply drawn from private sources, the same as it does as to the sources which the municipality itself has developed.

2. For the purpose of securing better fire protection and more adequate domestic service in the private water territories, and especially for the purpose of seeing that their distribution systems are properly laid out and ready to be incorporated into the city's system at some future time, the department has assumed to pass upon the location and character of additions to these distribution systems. Under their franchises the companies undoubtedly have the right to open the streets in the territories served by them for the purpose of installing water mains and appurtenances, but under the provisions of the charter, before they can exercise this right, they must apply to the Department of Water Supply, Gas, and Electricity for permits to do so. The department now prepares project sheets for the various extensions which the companies desire to install or which are demanded by the private consumers or by the fire department. These projects show the size and location of the mains to be installed and the location of the hydrants. After going through the hands of the engineers of the department, these projects are presented to the commissioner for his approval. If a project is approved, one of two courses is followed. In case the company has applied for a permit to install the main, the permit is issued. In case, however, the project has been prepared by the department on its own motion, or upon the petition of property owners or of the fire department, the commissioner issues an executive order to the water company directing it to install the main and hydrants as set forth on the project sheet.

Formerly, the matter of extensions was taken care of as a part of the hydrant rental contracts in the case of several of the companies, but during the past few years, in the absence of these contracts, the companies have been getting into the habit of complying with the commissioner's directions with respect to extensions. Recently, however, the commissioner had to go to court

to seek to enforce one of his extension orders. The judge expressed the opinion, already referred to, that the commissioner has no power to require a private company to extend its mains. If this decision stands, it will nullify in a very important particular the regulatory work of the department, and in case the companies take advantage of their legal rights, this decision may make it necessary for the city to give up the policy of attempting to regulate the construction of their distribution systems and, as an alternative, adopt the policy of extending the city's mains into their territories without regard to them. It seems obvious to every careful student of public utilities that competition and regulation by executive order are for the most part mutually exclusive remedies, and where the city is in a position, as the city of New York is, except with respect to a single company, to attain its purposes by direct action without submitting to prolonged litigation for the establishment of its regulatory powers, it would seem that the private companies should in their own interest adopt a conciliatory and reasonably compliant attitude.

3. As already stated, the private companies in New York City secure their supply from wells. Long Island offers very meager facilities for storage reservoirs, and so the companies have to depend for the most part upon continuous pumping direct into their distribution systems, with the assistance of standpipes in some cases to equalize the pressure and furnish a small reserve for the draft at the peak of consumption and in case of a big fire, a breakdown, or other emergency. Under these conditions it is pretty difficult and expensive for them to supply what is really a safe and adequate reserve for fire protection. The water department, therefore, is putting into effect the policy of establishing emergency connections between the city distribution system and the private companies' systems in order to enable the city to assume in part the conflagration and emergency hazard in the private water company territories, and thereby to insure a much better service to the people in these areas than would otherwise be available to them, or a service which, if made available through additional investments by the companies, would entail upon the city much larger payments for public fire protection than are now being made. The department is thus gradually in effect consolidating

for purposes of adequate service and economy of operation the various sources of supply, both municipal and private, which are now available for use in New York City.

4. The department has to operate a miniature public service commission plant for the purpose of investigating and adjusting complaints submitted to it by the private water companies' consumers. These relate to the quality of water, extensions of mains, character of service, general practices controlled by the companies' rules and regulations, and rates. The department's policy with reference to purity and sufficiency of supply and extensions of mains has already been described. In case of specific complaints as to adequacy of service or as to a company's practices in relation to its consumers, the policy is to make such investigation as may be necessary to determine the justice of the complaint. This is done either by a personal inspection or by a reference of the complaint to the water company for a report, or by both of these methods. After the facts have been ascertained and a decision reached, the matter can usually be adjusted without the issuance of a formal order to the company.

The commissioner has the right under the provisions of the regulatory law to establish, in respect to the companies' water supply, reasonable rules and regulations necessary for the convenience of the public and the citizens. The commissioner has not as yet put into force a uniform set of rules and regulations for the control of the several companies in their operations; nor has he issued a complete set of rules and regulations for any one of the companies, although many matters of detail have been taken up in individual cases. The department finds that the preparation of a uniform set of rules and regulations for the guidance of all the companies is beset with many difficulties because of the differences in their rates and their fundamental relations to the consumers, as well as because of the fact that it is deemed inexpedient to prescribe rules and regulations requiring a different and more liberal standard of service from the private companies than the standard adopted by the city itself. I refer to such things as the ownership and maintenance of meters by the utility, a matter over which the commissioner has no final control in the case of the municipal plant. In some cases the companies are more

liberal to their consumers than it is within the water department's power to be to the consumers on the city service. The department does not wish to establish uniform rules and regulations which would compel some companies to be less liberal than they now are, and at the same time it is embarrassed in establishing rules and regulations which would compel all the companies to be more liberal and progressive than the city itself is.

5. I have left till the last the most intricate and difficult of all the problems of regulation which the department has undertaken. I refer to the fixing of rates. Every rate problem, even under the simplest conditions found in common experience, is complex and difficult. But many special complexities and difficulties are encountered in the case of the private water companies in New York City. I cannot hope within the scope of this paper to do more than give a bare outline of these difficulties and of the ways in which the department is trying to meet them. Our work is still incomplete, and the degree of success attained still somewhat uncertain.

(*a*) *Basis of Valuation.* Difficulty has been experienced in securing the accurate records of cost in relation to some of the companies that would have enabled the department to use the actual-cost method as the basic factor in its valuations. Some of the companies have thrown their books open to examination by the department's accountant, while others have refused to permit such an examination and have supplied the department with only a limited amount of information as to their cost records. Under these conditions it seemed necessary to use the reproduction-cost method as the basic factor, but this method, always considerably theoretical and unreal, has been, in the case of the private water companies of New York City, subject to certain special limitations peculiar to the time and place.

The element of *land*, which in the case of the largest of the companies is an exceedingly important factor, was affected by the fact that the lands in use for water supply, lying for the most part within the limits of the Greater City, were inevitably decreasing in value as sources of water supply, while, at the same time, they were increasing in value for other purposes. In some cases the application of the reproduction-cost theory to land would have

led to a most fantastic result, since the value that would have been attached to the land for general real estate purposes would have been out of all proportion to its possible value as a source of water supply; although a value could be assigned to it for water purposes representing many times its original cost to the company.

With relation to the value of *wells*, *buildings*, and *pumping equipment*, it was found that the reproduction-cost method could not be used except with a liberal allowance for obsolescence and inadequacy, arising out of the fact that either the location of the wells and the pumping stations, or their use in connection with the water supply of the district served, had become or was about to become obsolete. In some cases, an estimate of value of all the separate items found in the inventory, on the theory that they were all live, "going" property, would have brought a total result out of all proportion to the actual value of the property as a whole under the conditions under which it was being operated or was likely to be operated in future.

The reproduction-cost method, if applied strictly on the basis of unit prices prevailing at the present time, would have brought fantastic results because of the abnormal price conditions which apply to both labor and materials. Yet nothing is more certain than that a water plant reproduced new at the present time would have to be constructed at a cost measured by most extraordinary prices. But the tempest that is sweeping across the face of the world leaves us all in doubt as to how long abnormal prices will continue, and as to whether or not they will ever get back to the old levels. So far as my experience goes, most engineers expect the continuance of the present high prices for a time at least long enough to swallow up the three- or five-year period often used as a basis in fixing unit prices.

In meeting these several difficulties, we made use of the reproduction-cost method, but applied it with certain qualifications. For example, we assumed that the physical conditions on the basis of which the estimate was made were the *original conditions*, and not those now existing. In particular, the item of *pavements*, in so far as they represented construction installed after the installation of the mains, was disregarded. With reference to *land* we excluded as obsolete those lands which had become too valu-

able to be continued as sources of water supply when the amount of water that could be taken out of them was considered. We also excluded lands which were unnecessary for water purposes, but which had been acquired, perhaps wisely from the financial point of view, at the same time when the water-bearing lands joined with them had been acquired. We also excluded lands acquired for water-supply purposes which had never been put to use, and which, under the circumstances surrounding the operations of the company, in all probability never would be put to use as water lands. In fixing the value of lands for water-supply purposes, we took into consideration the fact that so far as they are necessary from the point of view of the private company's continued operation they are held subject to the burden of public service which prevents the owners from releasing them for other uses without public consent. Our valuations were commenced during a period of normal prices, and were based upon average prices during the period of from three to five years immediately preceding the European War. Even now, in applying our valuations, we would make use of the old prices. Of course, a company which is compelled to make additional investments at the present time ought to receive consideration on account of the extraordinary cost of the portions of its construction undertaken during this abnormal period. Such consideration should be given, however, not in the form of increased unit prices, but in the form of extras applying to the work actually done during the period, just as extra allowances are made for other peculiar conditions, such as the presence of rock, the installation of pipe lines below the water level, etc.

(*b*) *Method of Applying Depreciation.* Water-works systems are usually regarded as long-lived properties, but the conditions affecting the private water companies on Long Island are somewhat peculiar in this respect. In the first place, as their supplies are local and as no large storage capacity has been or can be provided, the element of masonry construction in the form of reservoirs and aqueducts is almost entirely absent. Then again, the wells, buildings, and pumping stations, which in any case are not very long-lived, are, under the circumstances that prevail with these companies, subject to rapid depreciation on account of ob-

solescence and inadequacy. Part of this depreciation is what might be called artificial because of the potential competition of the city plant and the big fact staring the companies in the face that when the city takes over their service or extends its own service into their territories, these portions of their property will no longer be of any particular value for water purposes, as the city now has an entirely different source of water supply and a different method of operation. Even the distribution systems, which, under ordinary circumstances, are properly regarded as long-lived property, are, in the case of these companies, subject to comparatively rapid depreciation because of inadequacy. The small mains which have been deemed sufficient in the outlying sections of the city will have to be replaced sooner or later as these sections are built up more closely and as they develop a demand for water supply and fire protection commensurate with city standards. It has been necessary for us, giving consideration to all these elements, to regard the companies' plants as a whole as short-lived properties. We applied the straight-line method of depreciation because it is more appropriate under these circumstances, and also because it is simpler than the sinking-fund and equal-annual-payment methods.

(*c*) *Effect of Actual or Potential Competition upon the Rate of Return.* One of the companies is protected from immediate competition by the city by a legislative act. This, however, is subject to repeal at any time. All the other companies operate subject to the danger of municipal competition. Indeed, in some cases, the city already has its trunk mains through their territories distributing water to districts on both sides of them. In one ward of the borough of Queens, having a population of about 150 000, the company that is supplying the general service was subjected, a few years ago, to the competition of a rival which had picked up and revived an old franchise long fallen into disuse. This rival established a pumping station, and went into business with the avowed purpose of supplying the large consumers in the manufacturing district in one corner of the ward; and, without making any effort to secure domestic consumers, it proceeded to put into effect a competitive rate for industrial plants even lower than the city's rate and certainly lower than any rate

that would yield a fair return if applied uniformly to all the consumers who are being served by the older company. As a result, the new company, although now having only one large consumer and eight small ones, is now taking away from the company rendering general service net revenues representing nearly two per cent. upon the latter's necessary investment. The older company could get a seven per cent. return on its investment, if it had even the one large consumer in addition to its own, at rates that would yield only about five per cent. with the consumers which it now has. Ordinarily, in the process of regulation of public utilities, the presence of actual competition or the danger of potential competition would lead the regulating authority to allow the company whose rates are being fixed a higher rate of return upon its investment than would otherwise be necessary, this higher rate being based upon the increased risk to both investment and revenues caused by competition. But in the case of the private water companies in New York City it is clear that a higher rate of return upon the investment, reflected in higher water rates or poorer service than would otherwise be necessary, would have the direct effect of stimulating competition and thereby increasing the risk on account of which the higher rate of return was claimed. Ever-increasing danger to the investment would be the result, which logically would require further increases in the rate of return allowed. In other words, the application of the usual rule in relation to the rate of return upon the investment would render regulation absolutely nugatory. We took the position, therefore, that the danger of competition should have, if anything, the opposite effect upon the rate of return to be allowed, since the first duty of the regulating authority, from the point of view of the interest of the corporation whose rates are being fixed, is to protect the investment. We believe that the best way to protect the investment, under the circumstances prevailing in these cases, is to keep the rate of return down close to the minimum that will cover the cost of securing money; for in this way charges can be reduced or service improved and the dangers of competition minimized, with a resultant increase in the safety of the investment and the dependability of the revenues from operation.

(*d*) *Effect of the Established City Rates.* As the city of New

York has invested enormous sums of money to develop an ample municipal water supply, and already serves directly more than 90 per cent. of its citizens, it is natural that the rest of them who, though taxpayers of the city, are still dependent upon private companies for water supply, should demand at least uniformity of rates and equality of service as the price of their acquiescence in the continuance of the private water companies in business. It is often supposed that a city by developing an immense water supply and doing business with a great many consumers can reduce the cost of water service per capita below what it would be if continued on a smaller scale. This is undoubtedly true under certain conditions, but it is no longer true in the city of New York when comparison is made between a city of more than 5 000 000 people, bringing its water supply from far-distant watersheds, and a restricted portion of the same city served by a private water company from local sources. Undoubtedly, if the municipal water works of the city of New York were owned and operated by a private corporation, the revenues derived from the rates would have to be more than twice as great as they now are, to provide the company with a fair return upon its necessary investment. It does not follow, however, that a private company serving one of the wards of the borough of Queens, and deriving its supply from wells located within the area of service, cannot operate at a profit while charging the same rates which the city now charges. Indeed, it is conceivable that the city rates might, under such circumstances, be too high. The points I am trying to make are, first, that the city rates, as such, are no indication of what the rates would have to be if the municipal plant were operated by a private company; and, second, that the rates charged for the general city service either by a municipal plant or by a private plant serving the entire city have no logical relation to the rates necessary to maintain a local investment in the service of a restricted district depending upon a local supply. Nevertheless, the fact remains that in establishing rates for the private water company territories, the commissioner has to keep in mind the public demand for uniform rates to all citizens of the Greater City wherever they may reside.

Another peculiarity of our situation is that the city on its own

service charges a uniform rate per unit for all water consumed if metered, whether the amount be large or small. This uniform-rate policy differs from the policy usually adopted by private water companies, and, for that matter, by public-service commissions in fixing water rates. But for reasons which the city considers satisfactory this theory of rate-making has become well established in New York, and it has become a matter of considerable importance that the rates of the private companies should be made to conform as nearly as practicable to the principles which govern the city rates. It is particularly important to the city that the companies should not be permitted to adopt a rate schedule favoring large consumers and giving them a lower rate than the uniform rate on the city service, for this would put a premium upon the activities of companies whose purpose would not be to render general service, but rather to take the cream of the business, leaving to the city that which is most expensive and least remunerative. We have, therefore, as our objective, so far as metered water is concerned, the establishment of rates that shall not be lower than the uniform city rate, but that shall approximate this rate as closely as the circumstances of the individual company warrants.

(*e*) *Distribution of Cost between Domestic Service and Public Fire Protection.* The water department does not have to pay taxes on its property within the city limits. On the other hand, it receives no compensation from the taxpayers for the water furnished for fire protection and other public uses. Indeed, heretofore, no attempt has been made even to estimate and record as a matter of bookkeeping the value of the free service rendered by the department or of the free service received by it. Obviously, however, this rule could not be applied by a rate-fixing body to a private water company, and thus it became necessary for the commissioner, in establishing the basis upon which the water companies' rates should be fixed, to determine the proportion of the companies' revenues which ought to be derived from the two services, respectively. After careful consideration of the several theoretical bases for this distribution which have been put forward by different authorities, the department decided that under New York City conditions it is proper to assume that the private

water companies went into business primarily for the purpose of selling water for profit to domestic and business consumers, and that the service which they are under obligation to render to the public is an incidental or supplementary one imposed upon them as a condition of the special privileges they enjoy for the occupation of the public streets with their pipes. This does not mean that this service must be rendered free, but merely that it should be charged for at cost as a supplementary public service. We attribute to public fire protection that portion of the investment which represents an increase over the investment that would have been required for a plant entirely adequate if required to furnish domestic and business service only. We also attribute to fire protection so much of the operating expenses as represents a similar increase over and above what the operation of a plant for domestic and business service only would cost. We do not maintain that this method is necessarily applicable under all conditions, and, possibly, in small towns or in suburban communities receiving their supply from larger municipalities, the Wisconsin method of treating fire service and domestic and business service as coördinate may be more appropriate to bring about a just and politic result. But, so far as the private water companies in New York are concerned, under the peculiar conditions there existing, we believe that the method being pursued is the right one.

After determining the portion of the revenues to be derived from public fire protection, which is usually paid for in the form of hydrant rentals, we concluded that it would be better to divide this contribution into two parts: one, a lump sum to be paid by the city on account of the general investment attributable to fire protection, and the other, a sum made up of hydrant rentals, these rentals to be fixed at a figure that will just cover the actual and necessary cost of the specialized investment in the hydrants and of their maintenance. This plan takes care of the general investment existing at the time when the rates are fixed, and also provides a reasonable basis for the extension of hydrant service in connection with the existing mains. We realize, however, that it needs to be supplemented by some method that will measure the proportionate cost of additional investment in distributing mains and other facilities installed from time to time. We have not

adopted the plan of charging to fire protection a fixed sum per mile of mains in service, nor a graduated scale by which different amounts would be charged for mains of different sizes. We recognize that either of these plans is a simple one, and that it may for practical purposes under certain conditions work out a reasonably just result. We think, however, that a still better plan, where proper administrative conditions exist, is to have the chief engineer of the water department certify the proportion of the cost of every additional main as it is laid that is properly attributable to and necessary for public fire protection, and to add to the company's investment for fire protection purposes the portion so certified, and upon this additional amount to pay the company a fair rate of return, say 10 per cent. per annum, to cover interest, depreciation, taxes, etc.

(*f*) *Going Value.* The United States Supreme Court has held in many cases that accrued depreciation should be deducted from the reproduction cost of a public utility's property. Some of the leading state commissions and courts have, on the other hand, held that "going value," so called, is an element to be taken into consideration in determining the amount of the investment upon which the rates should yield a fair return. This going value is not the same as the going value defined by Justice Brewer in the Kansas City water-works case, as the additional element of value attaching to a water plant with its connections established and earning a revenue as compared with a water plant constructed and ready to operate but without any connections or business. The going value recognized for rate purposes might better be termed "going cost," or the cost of developing the business, and the highest court in the state of New York has held that this value represents the accumulated deficiencies below a fair return upon the investment which have not been later made up to the company by profits in excess of a fair return. In the case of a company that has been prosperous, the going value for rate purposes would not exist, while in the case of a company that has had a long series of lean years and has only now begun to earn a fair return upon its investment, the element of going value might be a considerable one. This, of course, is exactly the reverse of the theory of going value, or good-will, in a purchase case where

the price is fixed by voluntary negotiations. For purchase purposes the property is made more valuable by profits, while for rate purposes it is made more valuable by losses! Apparently, the mandate of the United States Supreme Court requiring that depreciation be deducted in a rate case may be entirely circumvented by the application of the theory of going value, which may make up in the form of intangibles all or more than has been deducted on account of depreciation. We found in the case of one private water company that it had never had any prolonged period of leanness. On the contrary, through its hydrant rental and water purchase contracts it had received a very large proportion of its total revenues from the city, with the result that it was able to pay fat dividends almost from the commencement of operation. But owing to the profit derived by the company from the water contracts, and the prospect that the city might take still more water, the company was tempted to extend its plant and acquire new sources of supply far beyond the immediate requirements of the territory occupied by its private consumers. The result was that after a while, when the city no longer needed to purchase water from the company, the latter was left with an over-developed plant upon its hands and an inflated capitalization based upon the rich profits of its earlier years and the assumed appreciation in the value of its land for water purposes. Under these circumstances, it was not altogether unnatural that the over-developed plant should fall into a degree of disrepair and that the habit of paying a fixed dividend upon inflated capital should prove stronger than the desire to maintain the property in the highest practicable state of efficiency. At any rate, it appeared that the company had withdrawn, in the form of high dividends, profits well in excess of what is now regarded as a fair return upon such an investment, while at the same time it had neglected to make adequate provision for depreciation.

As the result of careful consideration of this case, we determined that where a company has made the payment of dividends its first aim and has been niggardly in its provision for the maintenance of its property and its service, it is not the function of the regulating authority to delve deep into the dust of the past and reconstitute the company's accounts by setting up an allowance

for depreciation, and thereby, perhaps, establish a "going value" for rate purposes even though the dividends withdrawn from the property have been high from the beginning. On the other hand, if a company, having the same investment and the same earnings, has, in a spirit of conservatism, properly kept up its plant and provided for depreciation, and as a result of this policy has been unable to pay to its stockholders dividends up to a fair return upon their investment, then the rate-fixing authority may properly take this into consideration and make an allowance for going value based upon such accumulated deficiency. It is in this way that a company's attitude towards the public service can properly be penalized or rewarded in connection with the fixing of rates, and it is in this way that the doctrine of the United States Supreme Court, requiring the deduction of accrued depreciation, can be reconciled with the doctrine of the New York Court of Appeals that going value shall be allowed in rate cases where there has been a deficiency in the amount of profits received from the business.

Discussion.

Mr. H. F. Dunham. I should like to inquire what special features tend to make the life of these water companies so short.

Mr. Wilcox. There are no reservoirs or large conduits which constitute so large a portion of the property in some water plants and which are very long-lived. The mains tend to be smaller than the requirements of the city's future demand; therefore there is a more rapid depreciation on account of obsolescence in the distribution system than would otherwise be the case. The pumping plant and the wells are short-lived properties anyway, and they are also subject to depreciation by obsolescence because of this great change that is coming over the water-supply situation in New York through the development by the city of the large additional supplies which will inevitably, sooner or later, make these portions of the private companies' plants obsolete, whether or not they are purchased.

HARTFORD WATER WORKS, PAST AND PRESENT.

BY W. E. JOHNSON, DIVISION ENGINEER, RESERVOIR DIVISION.

[*Read September 13, 1917.*]

The following paper has for its object a brief sketch of the growth and development of the Hartford Water Works from its incorporation to the present time, covering a period of more than half a century.

During the early part of this period the supply was taken by pumps from the Connecticut River, and later by gravity from a drainage area on the eastern slope of Talcott Mountain in the towns of West Hartford, Farmington, and Bloomfield.

Previous to the adoption of the plan for a water supply from the Connecticut River with pumps operated by steam power and located to the north of the city, various projects were considered. One of these, which attracted considerable attention and was favored by many, was to construct a canal from Hartford to Windsor Locks, located about twelve miles up the Connecticut River, and utilize a portion of the water thus obtained in developing power to be used in pumping water to an elevated reservoir from which the city would take its supply.

The Hartford Water Works was incorporated in 1853. In that year surveys, plans, and estimates were made and contracts let with the approval of the Common Council. The following year construction began.

The first annual report of the Board of Water Commissioners is dated April 23, 1855. This report is principally devoted to a statement of the situation and condition of the works when they accepted office, disclaiming credit for the work, as undertaken, and giving to their predecessors all the merits or demerits of the plan. The report consists of ten printed pages, and considerable space is given to criticizing the action of the previous board, pointing out mistakes and lack of judgment of the Common Council, engineer, and prominent citizens.

The plant as built consisted of a pumping station on the Connecticut River at the foot of Pleasant Street, a sixteen-inch force main one and one-fourth miles long, and a distributing reservoir at an elevated position in the western part of the city now known as the Garden Street Reservoir.

The pump was comprised of four cylinders set vertically, in which operated two lifting pistons containing the valves, the upper piston being operated by a hollow piston rod through which the rod of the lower set of valves worked. The cylinders had an internal diameter of 19 in. and a 16-in. stroke. The pumps were driven by gears having hard-wood teeth working from pinions on the main engine shaft. The bottom of the cylinders was located about 10 ft. above mean low water in the river, and they received the water through a 24-in. conduit extending from the pump well to an intake in the channel of the river, a distance of 140 ft.

The engine was of the condensing beam type, with cylinder 32 in. in diameter and 60-in. stroke. The engine and pump were built and installed by the Woodruff and Beach Iron Works, of Hartford, Conn.

The Garden Street Reservoir has a flow line elevation of 125 ft. above mean low water in the river, and was originally considered to be of sufficient elevation and capacity for a long period of time. The maximum depth was 30 ft. and the capacity 8 000 000 gal. It was soon apparent that the capacity of the reservoir was insufficient and the elevation such that the reservoir had to be kept practically full to give the required pressure, thereby necessitating the operating of the pumps longer and at more frequent intervals.

The pumps were first put in operation October 20, 1855, and continued to supply the city until the gravity supply was put in operation in 1867.

As early as 1857 the board found that there was a much higher consumption of water than the conditions warranted, attributed to waste from defective and improper plumbing and because during the cold season the water was left running to prevent freezing. They advised a general use of stop and waste valves on the services, and the appointment of an inspector whose duties would be to superintend the placing of new house connections and the

inspection of house plumbing and fixtures. They stated emphatically that, with the present capacity of the works, the necessity of checking the waste was of vital importance.

During the early period of the water supply, there seems to have been but little reliable data as to the approximate number of persons supplied with water, the water rates being based on the number of outlets and fixtures in the houses. The annual report of March 1, 1863, gives an estimate that the population supplied about 26 000, making a per capita consumption of over 51 gal. In the following table is given the average daily consumption by years from 1857 to 1866 inclusive, which were compiled from the pump duties.

Table of Consumptions.

Year ending March 1	Average Daily Consumption. Mil. Gals.
1857 (10 months)	.34
1858	.51
1859	.66
1860	.78
1861	.90
1862	1.10
1863	1.35
1864	1.54
1865	1.84
1866	2.15

In 1858 the board began investigations relative to an increased supply of water. Their report on the subject was submitted to the Common Council in April, 1860. This report recommended a supply of water by gravity from the hills to the west of the city, and urged the Common Council to take immediate action on the matter of an additional water supply. In succeeding years the board continued its investigation and called attention to the vital question of an additional supply.

There seems to have been, at an early date, a diversity of opinion and much discussion in the city whether new pumps with a reservoir at a more elevated position or a gravity supply from

Talcott Mountain should be adopted. The following paragraph, taken from the report of 1864, indicated the interest aroused in the public concerning the additional water supply.

"It is much to be regretted that, in so vitally important a matter as an additional supply of pure and wholesome water for the daily use of our growing city, attempts should be made to bias the public judgment in favor of, or against, this or that project, by anonymous and irresponsible writers who have neither investigated nor have means of investigating a subject of this character; and unless the voting class will have the wisdom to discard, utterly, all representations made upon this subject by anonymous and ignorant or interested parties, and base their action upon the authenticated results of careful investigations, made by experienced, skillful, and responsible engineers of known integrity and ability, we shall be very liable to fall into a very grave mistake in the matter and discover our error when it is too late to correct it."

It was during this period that all possible means for utilizing the total capacity of the pump and conserving the supply was made. The size of the air chambers on the pump was increased, the speed of the pump accelerated about twenty-five per cent., a thorough investigation relating to leakage from the force main and distribution was made, and later the supply was pumped directly into the distribution. The result of the last mentioned was to furnish unsatisfactory and turbid water, which probably had the effect of hastening the action tending toward a new and additional supply.

In May, 1861, the Common Council authorized the board to employ such assistants as needed to re-examine and report anew on the various projects for a water supply for the city. In consequence of which, the board employed competent engineers and chemists to advise with them, and, although extensive investigations and reports were made and submitted to the council, no definite results were obtained.

The question was finally brought to a definite conclusion in the fall of 1864, when it was referred by the court of Common Council to a city vote, and was decided in favor of a supply by gravity from Trout Brook by a vote of 1 510 for and 508 against the project.

The plan for an additional supply submitted by the Board was approved by the court October 11, 1865, and contemplated impounding and taking water from Trout Brook in the town of West Hartford, and immediate steps were taken to carry out the plan.

At the very beginning of the gravity project the board was confronted with many obstacles in form of injunctions, lack of uniform action in the two branches of the Common Council, and want of adequate legislative rights.

In March, 1865, the board petitioned the General Assembly for an amendment to the city charter which would enable them to take water from Trout Brook in the town of West Hartford, which was finally granted.

The new supply by gravity was obtained by storing water from Trout Brook drainage area on Talcott Mountain. A dam was constructed a short distance below the junction of three branches of the stream, having a flow line elevation of 260.0 ft. above mean low water in the Connecticut River at Hartford.

Water was first introduced in the city from this source in January, 1867.

The following year Reservoir No. 2, located on the upper portion of the drainage area, was built, and an additional watershed of .8 square miles was added by means of a canal connecting Mountain Stream with Trout Brook. In 1870, the dam of this reservoir was raised five feet, increasing the capacity to 284 million gallons. Reservoir No. 3 joins Reservoir No. 2 on the south, with a water line at a slightly higher elevation, and was constructed in 1875, having a capacity of 146 million gallons. In 1880, Reservoir No. 4 was added to the system. This reservoir has a capacity of over 600 million gallons, and is located on a new drainage area, southwest of the original watershed. The water in this reservoir is conveyed to Reservoir No. 1 by a 24-in. cast-iron pipe. The yield of this reservoir was increased by the addition of Dead Swamp Canal two years later; this canal was not extended to its ultimate length until 1905, and now drains a watershed of 2.08 square miles. Reservoir No. 5, located between Reservoirs No. 1 and No. 2, was constructed in 1884. The last reservoir of the present system, known as the "Tumble-Down Brook Reservoir," or Reservoir No. 6, was built on a watershed joining Trout Brook

drainage area on the north. This reservoir added 765 million gallons to the storage, and is connected with Reservoir No. 5 by a 24-in. vitrified pipe line, and was completed in 1896.

The aggregate storage of the six reservoirs is 2 036 million gallons, and takes the water from a drainage area of 11.92 square miles, of which .68 square miles is water surface.

The safe yield of the present works has been estimated at 7.5 million gallons per day. In 1916 the average daily consumption was more than 10.5 million gallons. These figures indicate the importance of the new works now about brought to completion for the city of Hartford.

HARTFORD'S DISTRIBUTION SYSTEM.

BY FRANK BRAINARD, ASSISTANT ENGINEER.

[*Read September 13, 1917.*]

Previous to 1854, there was a small water-works system in this city owned by private parties. A small reservoir was located near what is now Park and Putnam streets. It received most of its water from springs, and the main pipes used to conduct it were principally wooden. These were evidently made by simply boring a hole lengthwise through a piece of wood about six feet long, then tapering one end and making a deep socket in the other, similar to the bell-and-spigot style in present use, while the outside received no other treatment than the removal of the bark. A length of this pipe was taken out of Kinsley Street in 1911, when we were laying a new main, and may now be found at the house of the Veteran Firemen's Association, where it is kept with other curiosities. It was originally about 6 ft. long and 8 in. in diameter, with a 2-in. hole or waterway. About two feet of this pipe was badly decayed and has since been cut off; the remainder, however, is in a good state of preservation.

In 1854 the present distribution system was started, and the Garden Street Reservoir built for distributing water pumped to it from the Connecticut River through 6 879 ft. of 16-in. cast-iron pipe, which is still in service. The engine and pump are also in a semi-serviceable condition, having been overhauled this spring, and run for a few hours, and are now in as good condition for use as possible in case of emergency.

Ten years after the system was started, — that is, in 1864, — there were 2 434 service pipes and approximately 32 miles of main pipe, which was of cast iron, with the exception of about 4 000 ft., the latter being cement with a sheet-iron lining.

But the new system had not been in use long before it became apparent that the Garden Street Reservoir was not large enough for the needs of the city, it having a capacity of only a little over

$8\frac{1}{2}$ million gallons. So, in 1866, the present reservoir system was commenced, and a 20-in. supply main was laid from Reservoir No. 1 into the city, where it was connected with the system already in use. Most of this new main was cement, lined with sheet iron, but in ten years' time a part of it was replaced with cast-iron pipe, owing to the number of leaks which developed, especially at the joints.

Between the years of 1864 and 1872, a large amount of this cement-lined pipe was laid, ranging from six to twenty inches in diameter, the last being laid in 1883. The greatest amount in service at any one time was about $18\frac{1}{4}$ miles. Because of the numerous leaks developing from time to time, it was decided in 1885 to replace all of this pipe with cast iron, so that at the present time the only cement-lined pipe still in service is about 700 ft. on Sumner Street, and this is to be renewed in the near future.

Because of the increased demand for water, two additional supply mains, a 20-in. and a 30-in., were laid in 1874 and 1896 respectively, and by 1895 the sixth reservoir had been built, their total capacity being 2 billion 100 million gallons. But, for all this rapid addition of reservoirs and supply mains, the city was constantly in danger of having to resort to the Connecticut River during every dry season, because of the great waste of water by consumers. To overcome this difficulty, it was decided in 1899 to meter all water except that used for fire purposes. Previous to this time, meters had been installed only in hotels, livery stables, and some manufacturing plants, the first ones being installed in 1877.

In 1901, with nearly 30 per cent. of the services metered, the average daily consumption was about 7 million gallons, or 84.6 gal. per capita, while in 1906, with 98 per cent. of the services metered, the average daily consumption was only 6.09 million gallons, or nearly a million gallons less. It was not until 1909, or eight years later, that the seven million mark was again reached, at which time the per capita consumption was 71.6 gallons, or 13 gal. per capita less than in 1901. It has not been necessary to resort to any other supply since the general installation of meters, but we have been very close to it, and without question would have been obliged to do so if it had not been for the meters.

As it was suspected that some of the factory fire-services were leaking underground, and that the privileges for the use of same were being abused, in 1907 twelve detector meters were installed on as many fire services. By the installation of these meters, it was estimated that 19 million gallons of water were saved, and that the revenue was increased about $330 the following year.

In 1907 we awoke to the fact that our system was in constant danger of pollution from the fire pumps located in several factories. These factory fire-systems are operated at a pressure much greater than that of the city, and the only protection in use at that time was a single check valve. If this should fail, the fire pump would discharge directly into our system. As most of these pumps receive their supply from the Park River, which is highly polluted, it was decided in 1907 that all these connections must be equipped with double check valve systems, fourteen of which are now in service.

These double check valve systems consist of two check valves so connected and fitted up that each one may be tested separately for leaks under any pressure we may see fit to use. There is also an automatic electric alarm system connected with them, that rings a bell in the office of the factory in case one of them is leaking when the pumps are in operation. These check valves were installed under our direction by the factory owners, who bear all cost of inspection and repairs. A monthly inspection is given them by men from the water department, and they are taken apart and cleaned once a year.

For some years previous to 1908 it was known that the small mains in the center of the city could not furnish adequate protection in case of a large fire. It was therefore proposed to lay a 24-in. main, or belt line, around the Conflagration Area, as defined by the New England Insurance Exchange in 1906. The inside of this area was to be gridironed with mains ranging in size from 8-in. to 16-in. This work has now been completed, so that it is possible to concentrate about ten thousand gallons of water per minute on any block in this area.

On Prospect Avenue, south of Albany Avenue, there is a sudden rise of ground known as Prospect Hill. This is one of the highest points in the city, and during periods of maximum draft

the water does not reach the top of the hill. In order to furnish fire protection to this section, check valves have been installed in the main pipe each side of the hill between two hydrant connections which are about 25 ft. apart. In case of fire, water is pumped by fire engines from the hydrants connected below the check valves into the hydrants connected above, and is thus forced up the hill through the main pipe, where it is made use of by hydrant streams.

With the introduction of the electric railway cars came the danger of electrolysis to our underground system. The greatest damage from this source occurred between the years of 1907 and 1912, at which time the railroad had twelve steel rails that were laid underground from the State Street car barn, through Grove and Commerce streets, to their power station, for a negative return system. These rails were not insulated, and as the water pipes were highly positive to the rails, the electric action was very great. It was necessary in 1909 to replace eight service pipes in the vicinity of Grove Street, which were leaking badly, due to this action. One of these pipes had been in service only three years, although their average age was ten years.

In 1909 the trolley company installed several wooden insulating joints in our mains near this danger section, in an attempt to break up the flow of electric current on our mains toward their power station. While these were partially successful, in that they stopped the flow on our mains at that point, they did not, however, help the situation to any great extent, as the current passed these joints by means of other underground structures, and returned to our pipes again, after passing. These joints consisted essentially of an ordinary pipe joint, with the lead space filled with wooden wedges, and a wooden ring slipped inside of the bell end of pipe, to keep the spigot end from "bottoming." A double joint of this kind was used for greater security, being made up in as small a length as convenient.

Five years ago the rails were removed and overhead wires substituted for their negative return system, since which time the conditions have been much improved, and to-day we have very little damage from this source.

Owing to the need of additional space in which to store pipe

and special castings, a tract of land situated at the corner of New Park Avenue and Flatbush Avenue, containing about six acres, was purchased in 1909. This storage yard is adjacent to the main line tracks of the New York, New Haven & Hartford Railroad. A spur track has been run into it from the railroad, and a trolley system constructed for the handling of pipes delivered there. All pipe and special castings for the use of this department are now received at this place, which we call the New Park Avenue Yard.

The meter department is located at the old storage yard on Union Street. All meters are tested here before being installed; they must register not less than 98 per cent. and not more than 100 per cent. of the water passing through them on a full flow, and the smaller sizes must register on a $\frac{1}{32}$-in. stream. It is planned to remove all meters at least once in three years, for cleaning and testing. The machine, carpenter, and blacksmith shops are also located at this yard, as well as the garage for the auto trucks and the barn for the horses used by this department.

On March 1 of this year there were in service 199.41 miles of main pipe, ranging in size from $1\frac{1}{2}$ in. to 30 in., with about three miles less than 4 in. in diameter. All mains 4 in. or over in size were cast iron with the exception of 700 ft. of 6-in. cement-lined pipe, and all less than 4 in. in diameter were galvanized wrought iron; there were 4 042 stop gates, 15 404 service pipes, and 15 077 meters. The service pipes were principally galvanized wrought iron, although there were some brass, lead-lined, and cement-lined pipes in use. The average life of a service pipe is about twenty-five years.

The estimated population supplied during the past year was 163 000, with an average daily consumption of 10.6 million gallons and a per capita consumption of 65 gal.

The pressure ranges from 10 to 100 lb. during periods of minimum draft, but is about 20 lb. lower during periods of maximum draft. This variation will be overcome, however, when the 42-in. supply main now under construction is completed.

Discussion.

Mr. McFarland. I am interested in your statement that over 90 per cent. of your service is metered, which is a large percentage. Have you a meter of water which is pumped or delivered at your station, so as to determine what percentage of the water is accounted for through meters?

Mr. Brainard. The water is all delivered by gravity; there is no pumping station. There is a master meter located at the reservoir, which meters all the water which comes into the city.

Mr. McFarland. What percentage of that water is lost? How much is the loss between the meters?

Mr. Brainard. There is about 85 per cent. of that which is accounted for on the small meters; about 15 per cent. is not accounted for.

Mr. McFarland. You stated your service pipes were wrought iron. Do you mean wrought iron or steel?

Mr. Brainard. Galvanized wrought iron.

Mr. McFarland. You don't use the steel pipe at all?

Mr. Brainard. No, sir.

Mr. L. M. Hastings. I was interested in what Mr. Brainard said about the electrolysis and the loss and injury to pipes from that cause. Now, we have suffered from that cause very greatly. The services that we put in will sometimes not last more than a year, and then be entirely corroded in that time. The Boston Elevated Company has taken some steps to regulate it, but there has been nothing that has been very effective. Now, as I understand it, you said there was an overhead return wire laid from your danger district back to the power station. Can you explain that a little more fully, so that we can see what that return feed is, and how it is arranged to reduce the leakage?

President Saville. On that matter of electrolysis, I should like to say that we have had very little trouble. Previous to about five or six years ago, that matter was handled by some electrical engineers that were employed spasmodically by the board. Within the last four years we have been handling that through another assistant than Mr. Brainard, and I will ask Mr. Garratt if he will kindly reply to that question which has just been asked, — about the back flow.

Mr. Garratt. The railroad return feeders consist of twenty-one 1 000 000 circular mill cables, which connect with the rails and take the current back from six different points. These points are located within a half mile north and south of the center of the city and between the railroad and the river. Since they have installed those return feeders it has changed the danger area, the positive area in the city, from the southern end of the city to points near those bond connections.

Mr. Hastings. What do you say as to the danger from electrolytic action?

Mr. Garratt. The danger has been reduced in area. It has changed the locations, and whether we are going later to have bad conditions in those areas, we don't know.

Mr. H. F. Dunham. Have you made investigations to know how much you are carrying on your pipe lines?

Mr. Garratt. Yes, we have current load stations where we take measurements each year. The current has been materially reduced by the installation of this new return feeder system of the railway.

Mr. Dunham. Is there any difference between summer and winter?

Mr. Garratt. I have not looked into that. We have taken observations in winter as well as in summer.

President Saville. I will say, regarding the double check valve system Mr. Brainard spoke of, that within a year the board — recognizing the rather ridiculous and illogical condition which arises from a city which is about to spend hundreds of thousands of dollars to safeguard its water supply and filter it and see that there is no pollution in any way whatsoever — has passed a vote prohibiting the extension of the double check valve system, so that there shall be no more physical connection with polluted sources even if it is governed by a so-called safeguard.

ENGINEERING ON THE ADDITIONAL WATER SUPPLY FOR THE CITY OF HARTFORD.

BY H. W. HORNE, DIVISION ENGINEER.

[*Read September 13, 1917.*]

The Board of Water Commissioners of the city of Hartford have just finished an impounding reservoir of $9\frac{1}{2}$ billion gallons capacity for an additional supply to its present system. This reservoir, known as the Nepaug Reservoir, is located in the towns of Canton, New Hartford, and Burlington, and is about fourteen miles west of Hartford, the nearest railroad station being Collinsville. The reservoir was formed by building two dams and a dike: one dam, a concrete masonry structure, on the Nepaug River, which flows into the Farmington River $1\frac{1}{4}$ miles above Collinsville; the other dam, an earth structure with a concrete core wall carried to ledge rock, on the Phelps Brook, which flows into the Farmington River $1\frac{1}{4}$ miles below Collinsville, and the dike, built of earth with a concrete core wall, at a low divide at the northeast end of the reservoir. The water from these streams is backed up over a broad flat divide between them, where the water will be 27 ft. deep with the reservoir full. The watershed supplying the reservoir covers 32 square miles in area.

Besides building the Nepaug Reservoir from which the city of Hartford will get its water supply, it was necessary to build a compensating reservoir of 3 billion gallons capacity, to store water to compensate the mill owners who would be deprived of the flow of the Nepaug River and of the Phelps Brook. This reservoir, known as the East Branch Reservoir, is located in the towns of New Hartford and Barkhamsted on the east branch of the Farmington River, about one mile east of the village of New Hartford. The dam on this river, an earth structure with a concrete core wall, carried to ledge rock, is under construction at the present time.

The engineering work which was necessary for the building of

the Nepaug and East Branch reservoirs may be divided into two groups, — preparatory engineering and constructive engineering. Under preparatory engineering is classed triangulation, bench leveling, property surveys, topographical surveys, including detailed topography at the dam sites, and all work necessary for the preparation of the contract plans. Under constructive engineering is classed all lines and grades given for construction work and all measurements taken for estimates for payments to the contractors.

In any engineering project of the magnitude of this work, the surveys must be accurately tied together, and for this purpose a triangulation system was first established in each reservoir basin, suitable stations selected, and a base line measured. At the Nepaug basin there were nine stations, and at the East Branch basin ten stations. The angles at each station were read twelve times. The reservoirs are about four miles apart, and although entirely separate projects, it was thought best to tie the two triangulation systems together and connect them with the West Hartford reservoirs. For this work two United States Geological Survey triangulation stations were selected: one, "Talcott," on Talcott Mountain in Avon, about eight miles east of the Nepaug Reservoir, and the other, "Johnny Cake," on Johnny Cake Hill, in Burlington, about five miles southwest of the Nepaug Reservoir. These stations are 57 361.8 ft. apart, and, with this distance as a base line, a system of stations was established and connected with the two local systems at each reservoir. There were fourteen stations in the large system, and the angles were read sixteen times at each station.

Bench levels were run from No. 1 reservoir at West Hartford to each reservoir location, and numerous bench marks established for use in topographical surveys and for construction work. These bench marks were for the most part spikes driven into the roots of large trees.

Property surveys were made covering the area needed for each reservoir, and, although only parts of the farms were required, the whole farms were surveyed. Traverse lines from which the property lines and corners were located were run around each parcel of land and these traverse lines tied to the triangula-

tion stations. At the Nepaug basin 60 parcels, covering 2 466 acres of land, were surveyed, and at the East Branch basin 51 parcels, covering 1 683 acres. To determine the actual amount of property needed for each reservoir, the flow line of the reservoirs was staked out on the ground with stakes located about 100 ft. apart and standing up above the ground 2½ ft. The flow line of each reservoir measures about 11 miles in length. The water surface of the Nepaug Reservoir at elevation 485, the flow line, covers 851 acres, and the water surface of the East Branch Reservoir at elevation 422.5, its flow line, 437 acres.

A topographical survey was made at each of the two reservoirs with transit and stadia, and maps were plotted with horizontal scale one inch equals two hundred feet and five-foot contour intervals. From these maps the approximate capacities of the reservoirs were figured. The traverse lines for the stadia surveys were tied to the triangulation stations and to the property survey stakes. At each reservoir the stadia surveys covered areas around the reservoirs for about fifteen feet in elevation above the flow lines. In flooding the areas for the reservoirs, a number of highways were necessarily submerged, so that new highways had to be built to take the place of the ones discontinued. This required numerous topographical surveys over prospective routes, to determine the best and most economical ones to adopt. At the Nepaug Reservoir, 4.3 miles of new highways were built, and at the East Branch, 3.0 miles; 7.0 miles and 5.8 miles were discontinued at the Nepaug and East Branch reservoirs respectively. The field parties making stadia and property surveys usually consisted of an assistant engineer, an instrument man, and two rodmen. Except at the beginning of the work, when there were three field parties, two parties made all the surveys and gave all lines and grades when construction work was in progress.

The dam sites were tentatively located on the ground, and each site was then cross-sectioned and enough elevations taken to plot contours at two-foot intervals. At the Nepaug Reservoir there were three dam sites, — the Nepaug at the north end, the Phelps Brook at the south end, and the East Dike at the northeast end. At the East Branch two sites were cross-sectioned for study, located about 2 000 ft. apart. To finally decide on the best possible

locations for these dams, diamond drill borings were put down at each site and the depth to rock and the character of the rock penetrated determined. At the Nepaug site, 15 holes were drilled; at Phelps Brook, 6 holes, and at the East Dike, 4 holes. At the two sites on the East Branch, 23 holes were drilled. Besides the drill holes, test pits, varying in depth from 5 to 29 ft., were dug, to determine the character of the material overlying the rock and to locate suitable materials for concrete and earth embankments. At the Nepaug 73 pits were dug, and at the East Branch 52 pits. The field parties located all borings and pits, and these were plotted on the contour plans of the dam sites and the information regarding them noted.

The construction work at the Nepaug Reservoir was completed under seven main contracts, the Nepaug dam, the Phelps Brook dam, the East Dike, the Clear Brook road, the Nepaug road, and two contracts for clearing the reservoir site. The engineering work for these contracts was handled by two field parties of four men each, with engineering inspection on each contract. The two large dams were started about the same time with a field party located near each dam; the party at the Nepaug dam looked after the East Dike and the clearing contracts, and the party at Phelps Brook dam looked after the two road contracts. The Nepaug dam required the most attention as regards line and grade, as it is built on a curve with the upstream face vertical, the non-overflow section of the downstream face on a vertical curve, and the overflow section, a series of steps. It was built in radial blocks with expansion joints between them, about 40 ft. long on the center line, which was on a curve with a radius of 390 ft. A tower, 40 ft. high, was erected over the center of this curve, on which a transit could be set and the lines of the expansion joints given. There were 14 blocks in all, and the lines and grades of each were figured as separate problems. It required all the time of an assistant engineer to keep computations ahead of the points, as they were needed by the carpenters building forms. For giving points, a set of rectangular coördinates was used in conjunction with the expansion joint lines set from the tower. To hold the coördinate lines and the expansion joint lines, concrete piers were set in the ground, and bolts with crosses on them concreted in the

piers at the intersections of these lines. There were 28 of these piers built.

Copper bolts for bench marks were set in the concrete on the top of each spillway step, as the work progressed, and the elevations carried up on them. Besides the work of laying out the dam, the forms had to be checked after they were erected, before the concrete was placed. Each month, estimates of quantities of work done had to be made for payment to the contractor, and the measurements for these estimates and the calculations of quantities required considerable time.

The Phelps Brook dam was built on a compound curve in order to locate the core wall on ledge where it showed at the highest elevation at the dam site. The lines and grades were given on rectangular coördinates, however, and the differences in the slopes of the embankments, due to the curves, were figured on these coordinate lines. This system simplified the field work greatly. The East Dike and the dam at the East Branch are both straight, and the giving of lines and grades was comparatively simple.

Besides the seven main contracts for the Nepaug reservoir there were five other contracts connected with the work which required engineering attention, three for moving cemeteries and two for building a filtration plant for the Collinsville Water Company. Three main contracts have been let for the work at the East Branch Reservoir, — the Richards Corner dam, the Barkhamsted road, and the East Branch Highway Bridge. The engineering work at the East Branch Reservoir is being handled by the field party from the Phelps Brook dam, as the latter was finished about the time the former was started.

On November 29, 1916, the gate at Phelps Brook was closed and the basin allowed to fill. On December 23, the gate at the Nepaug dam was closed. The water in the Nepaug basin reached the divide between the two basins first on March 29, 1917, and flowed into the Phelps Brook basin. Both basins reached the same elevation on April 2. While the basins were filling, different contour intervals were located by transit and stadia distances to the water's edge from permanent stations set around the reservoir just above the flow line. This work was done to obtain an accurate figure for the capacity of the reservoir, and was carried on in

the winter months, when there was no construction work in progress.

Discussion.

Mr. Homer R. Turner. I should like to inquire if, in making the property surveys, the traverse lines were run by steel tape or stadia measures?

Mr. Horne. Tape measures.

Mr. Frank L. Fuller. I should like to inquire your practice in the stripping of these reservoirs. It occurs to me also that in doing this topographical work you must have had a pretty good opportunity to check up the government map, and I should like to ask how well that agreed.

Mr. Horne. There was no stripping of the reservoir. The trees were all cut down even with the ground, and on a strip of fifteen feet elevation around the edge of the reservoir the stumps were all blown out. There has been no stripping. On the topographical survey we found that the government maps were not particularly good in that locality.

President Saville. In reference to the last statement, — that the topographical maps were not very good, — I should like to make an explanation, because I happened to be very intimately acquainted with that particular thing. The late Professor Shaler was the father of the topographical survey in the United States. He was professor of geology in Harvard, and much interested in the Lawrence Scientific School, a department of Harvard University. With the far-seeing knowledge of the necessity of a topographical survey of the United States, Professor Shaler got a very small appropriation to do some topographical work and sent a survey party out from the Lawrence Scientific School to do it. That topographical work was first undertaken right in the quadrant around Hartford, right here in Connecticut, and the fact that it is so poor is due to the very small appropriation that was made, to the lack of knowledge of topographical work, and to the fact that young men who were not the expert topographers that the United States Geological Survey has to-day were put on the work. The fact that it is as good as it is I think is a remarkable comment on Professor Shaler's work. That work will un-

doubtedly have to be done over again, but it has stood excellently as a prototype for the excellent work of the present geological survey. That is the reason this work is so poor in Connecticut.

Mr. Frank L. Fuller. I should like to ask if this base line was measured with a steel tape, or whether it was checked from the topographical work. The base line which I think was eight or ten miles long.

Mr. Horne. It was checked up with a local base line.

President Saville. It was the side of one of the primary triangles. We used as a base line the side of a primary triangle of the Geological Survey.

Mr. Fuller. Didn't you have to establish stations?

President Saville. We established stations and then worked up our triangulation from the base line, which was the side of the primary triangle of the Geological Survey, and in that way we did not have to go to the refinement of measuring the base line ourselves.

THE DESIGN OF THE DIVERSION CONDUIT AND WASTE WORKS OF THE RICHARDS CORNER DAM AT NEW HARTFORD, CONNECTICUT.*

BY R. E. WISE, DESIGNING ENGINEER.

[*Read September 13, 1917.*]

The Richards Corner Dam, which is being built by the Board of Water Commissioners of the city of Hartford, Conn., is to store the flood waters of the east branch of the Farmington River, and the stored waters will be let flow down the river during periods of low water in the river, to compensate in kind the mill owners, on the Farmington River below, for the diverted waters of the Phelps Brook and Nepaug River, the flows of which have been taken for the new water supply of Hartford.

This paper will deal with the design of the diversion works of this dam, namely, the stream control conduit, the spillway, and waste channel.

One of the first and most important problems that confronted the engineers in planning the construction of this earth dam was the method of taking care of the flow of the river during construction. The watershed of this river above the site of the dam is about 61 square miles, being long and narrow, — about 16 miles long by 4 miles wide, — with steep and rugged side slopes, which produces a flood condition quickly after a storm. To protect the foundation work which was to be carried 50 ft. or more below the bed of the river and the dam itself until completed, a concrete conduit was designed with such a carrying capacity that it would discharge any flood flow that it was thought might come during the period of construction of the dam. In studying probable flood flows of this river, records of rainfall and run-off flows were only obtainable back to March 1, 1912, at which time the Water Board of Hartford began taking records. Since that date two

* The engineering work of this dam is under the direction of Caleb Mills Saville as chief engineer, with Frederic P. Stearns and John R. Freeman the consulting engineers, and the writer in charge of the designing division.

large flows have been recorded, the maximum on February 25, 1915, on which date 2 to $2\frac{1}{2}$ in. of rain fell in eighteen hours, producing a maximum run-off of about 52.5 cu. ft. per second per square mile, the crest of the flood being reached about eight hours after the beginning of the storm. There was a small amount of snow on the ground, which had been softened by several days of warm weather. The run-off from this storm was 1.8 in. on the watershed, about 80 per cent. of the rainfall. The other flood recorded was on October 26 and 27, 1913, 5 to $6\frac{1}{2}$ in. of rain falling, which produced a maximum run-off of 44.5 cu. ft. per second per square mile, the crest of the flood being reached fourteen hours after the beginning of the storm. Recorded flood flows of other rivers were studied, and one in particular may be noted, — that of the Nashua River at the site of the Wachusett Dam on February 13, 1900, at which time 3.2 in. of rain fell with ice on the ground, and produced a maximum run-off of about 80 cu. ft. per second per square mile, the crest being reached eleven hours after the beginning of the storm. The drainage area on this river is nearly twice as large as that of the East Branch, and it contained quite a large number of swamps and ponds which would tend to store water and help mitigate the floods. With the above data at hand, it was thought that a conduit which would pass 100 cu. ft. per second per square mile of watershed would safely provide for any flood liable to occur during the period of construction.

Considerable study was given to the location and alignment of the conduit. Borings taken along the east bank of the river indicated a sharp shelving off of the rock surface. A study was made for a location to effect economy in construction, minimum length, and excavation, by constructing the conduit on a 400-ft. radius which would place the central portion well into the hill, and a good rock foundation for this portion would be assured. This would have involved building partly on rock and partly on earth toward the ends. A straight-line alignment was finally decided upon, with a location well into the bank in order to secure, if possible, a rock foundation throughout the entire length of the conduit.

To divert the flow of the river to the conduit, a cofferdam of

earth was placed across the stream at the head of the conduit. This dam was carried to a height of 15 ft. above the crown of the conduit and forms a basin above, which when at a level sufficient to make the conduit discharge 100 cu. ft. per second per square mile of watershed would contain 250 million gallons, or about 0.4 in. of rain over the entire watershed. The ponding effect of this basin would be to delay the crest of a flood caused by a 100 cu. ft. per second per square mile of watershed run-off to eighteen hours after beginning of storm if the rate of rise was approximately that of the floods noted on this river and the Nashua River.

To divert the normal flow of the river to the entrance of the conduit, it was necessary to excavate a diverting channel about 6 to 8 ft. deep, 20 ft. wide at the bottom, with side slopes of 1 on 2. To reduce the seepage under the cofferdam to the core wall trench, of the water from this channel, the bottom and sides were lined with 9 in. of loam, over which was placed a layer of gravel 6 in. thick, to prevent scouring the loam.

A great deal of study was given to the design of the entrance to the conduit. It was realized that the maximum discharging capacity could be secured only by careful attention to the shape and finish of the bell-mouth entrance to the conduit, because cross currents, eddies, and surges must be avoided. It was thought that the bell-mouth should be symmetrical in horizontal cross-section out to a point where the velocity becomes fairly slow, which point was estimated to be where the width of the entrance was fully double that at the throat of the bell-mouth. The sides of the flaring walls to the entrance of the bell-mouth were made vertical at the tunnel entrance, and made to pitch back to a generous batter in a sort of warped surface out to the ends. These side walls were carried out at an elevation above the estimated flood flow line of 100 cu. ft. per second per square mile of watershed, to a distance equal to the width of the tunnel entrance, so that water approaching from the side would not tumble over them and disturb the smoothness of the flow at the entrance.

The bottom of the bell-mouth was founded on earth, as the rock foundation shelved off at the entrance to the conduit. This bottom was excavated to a depth of about 18 in., refilled with

loose broken stone, and smoothed over with a lean mixture of concrete.

The invert of the conduit was carried out to a point 10 ft. beyond the mouth, and was curved in order to make it more stable against an upward pressure which would be caused by the difference between the upward pressure due to the height of the water in the pond above the conduit and the downward pressure due to the height of water above the invert, which would be less than the pond elevation by the loss of head at entrance.

The transition at the entrance to the conduit from an approximate square with 21 ft. sides to the standard horseshoe section of the conduit was made in 25 ft. The standard section of the intrados of the conduit is of the typical horseshoe shape, and is 21 ft. wide and 17 ft. high, having an area of 279 sq. ft. The total length of the closed conduit is 315 ft., with expansion joints placed approximately 30 ft. apart. At these expansion joints are imbedded 6 in. by $\frac{3}{8}$ in. ingot iron water stops, extending entirely around the section. The strength of the conduit section was varied to meet the different imposed loads through the dam by changing the extrados, three different sections being used. To prevent a flow of water following along the outside of the arch, water stops were built about 10 ft. on centers for a distance of 100 ft. below the core wall.

As there is to be a gate well built into the conduit in the upper portion, at the completion of the dam particular attention had to be given to the strength of the invert of the conduit below this point on account of the upward pressures that might come upon it. The conduit below this gate well will be empty after the completion of the dam, and the full pressure from the water in the reservoir may be exerted beneath the invert. For a distance of about 40 ft. above and below the location of the core wall, the rock beneath the invert was drilled and grouted and the maximum thickness of the invert was carried along this distance. As there would be a diminishing upward pressure below the core wall, the invert was made thinner below the grouted portion, and drill holes were made through the invert of this portion to assure no upward pressure.

At the outlet of the conduit the retaining walls were flared

slightly and the apron between them built with a descending grade, hoping thereby to secure the effect of a divergent Venturi tube in diminishing the velocity of the water.

At the completion of the dam there will be built in the conduit, 30 ft. above the location of the core wall, a gate well containing two 3 ft. by 5 ft. sluice gates, which will be operated to pass the water from the reservoir to the stream below as the requirements of the mill owners below demand. After the installation of this gate well in the conduit, at the downstream end of the tunnel, will be built a concrete curtain wall with an opening heavily barred, the idea being to prevent some crank with a box of dynamite from walking up the conduit and firing it off close to the two outlet gates.

To discharge the flood waters after the completion of the dam, a spillway or waste weir is located on the west bank of the reservoir where rock outcrops and test pits indicated ledge rock near the surface. The waste weir will have a total length of 290 ft., and is carried upstream at right angles with the dam at its west end. This weir provides for a discharge of 10 000 cu. ft. per second under a 5-ft. head, which is equivalent to a rate of 163 cu. ft. per second per square mile of watershed and would discharge a flow of 200 cu. ft. per second per square mile run-off with a 5.6 ft. head. This run-off of 12 200 cu. ft. per second would make the water stand in the upper end of the waste channel two or three feet above the crest of the weir, and the pond elevation would be from 6 to 7 ft. below the top of the dam. The weir will be founded on rock throughout its entire length, and built of concrete with its crest $12\frac{1}{2}$ ft. below the top of the dam and rounded on its downstream side sufficiently to cause the water to follow the masonry. Below the rounded crest, at the surface of the rock, will be a 10-ft. beam, 5 ft. of which will be covered with concrete, to receive the impact of falling water. The section of the waste weir has a wide base which ought not to slide or overturn. Bronze sockets for flashboard pins will be spaced about 10 ft. on centers along the crest, for the possible use of flashboards.

For the waste channel a rather favorable location exists, in that the surface of ledge rock was of moderate depth to a distance

below the dam where the discharging water would not affect the integrity of the dam by flowing in an earth channel. The waste channel runs approximately at right angles to the dam, and is to be excavated into the rock to a point far enough below the center line of the dam to prevent any danger of wrecking the main structure by overflowing the rock channel, and it is of such section — 25 ft. to 35 ft. width at bottom with 4 on 1 side slopes — that retaining walls will be unnecessary. It was thought desirable to excavate into the rock for the portion opposite the waste weir and opposite the end of the dam only enough to keep the water from rising too much above the crest of the waste weir in the event of a flood of 200 cu. ft. per second per square mile run-off. At a distance 90 ft. below the center line of the dam, a steep grade ($9\frac{1}{2}$ per cent.) was given to the channel, to greatly accelerate the velocity of the water and reduce its level and to continue to keep within the rock channel to a point approximately 300 ft. below the center line of the dam, where even in the case of a great flood the damage done by the water flowing over the sides of the rock channel beyond this point could not affect the integrity of the dam. At about 350 ft. below the center line of the dam, the rock surface disappears below the bed of the channel, and at this point the grade of the channel changes from $9\frac{1}{2}$ per cent. to 1.3 per cent., and the channel is wholly in gravelly material until it reaches the river 500 ft beyond. This earth channel is to be a rough steam shovel cut approximately 10 ft. deep and 30 ft. wide at the bottom, with rough shaping of the side slopes. It is expected that great floods will cause washouts along this part, but such damage will not affect the dam, and it was thought better to take the risk of such damage along this part than to incur too much expense in the construction of this portion of the waste channel.

Discussion.

Mr. Frank L. Fuller. As I understand it, this waste conduit is a prominent part of the construction. Is it not so?

Mr. Wise. Yes, it is.

Mr. Fuller. Well, I don't exactly understand how that was closed, — the form of gate that was used to close this conduit.

Mr. Wise. Just above the core wall is to be a gate well built

into the conduit in which there are two 3 by 5 sluice-gates. These gates will be kept closed until they are opened to pass the water down the conduit to the river below as the mill owners demand. During the spring there is plenty of water in the other branch of the river, and the mill owners will not want this water. Then in the summer, when there are low flows in the other river, we will let the water out from this reservoir through these gates into the conduit, which will pass the water into the river down to the mill owners below.

Mr. Fuller. Would this conduit be used to aid the spillway in the time of an excessive flood?

Mr. Wise. Why, it could be used. We don't think it will be necessary. We think we have provided a sufficient spillway to take care of any flood we think possible to come.

Mr. ———. Will any provision be made for the utilization of power from this dam?

President Saville. None. It might perhaps be interesting to say, in relation to this, that this is one of the few, if not the only case, of legal compensation in kind. This is the case for this particular reservoir: The legislature gave the Water Board of Hartford authority to take this and to compensate the mill owners, but several of the property owners claimed that, while the legislature had a right to allow condemnation for water-supply purposes, this was not a water-supply purpose but, as they claimed, a way for the city of Hartford to avoid payment of damages, therefore not constitutional. The case was carried up to the United States Supreme Court and decided in favor of the city of Hartford, and it therefore formed rather a valuable example for cases of similar character later.

Mr. Fuller. Then, do I understand, Mr. President, that the mill owners have some claim on the water?

President Saville. The mill owners have every claim. This reservoir is entirely built for the use of the mill owners. The city of Hartford has no rights in it as a water-supply proposition. It will be operated at the expense of the city of Hartford, but at the behest of the mill owners as they desire this water. And the probability is that once, at least, or perhaps twice during the year, the water may be entirely drawn out of this reservoir, — it may

be entirely emptied, because it is for compensation purposes pure and simple.

Mr. Hiram A. Miller. Doesn't that destroy the value of this for water supply for the city? The time when the city will want this water is when there will be a low flow, and that is the time the mill owners will want this water.

President Saville. The present development is thought to be sufficient for the next thirty-five or forty years. In order to get the supply which we definitely needed at once, we were content to let that question rest until the future, for the next generation to settle.

Mr. Fuller. That is, it is possible that this, later on, might be called into use as a supply for the city?

President Saville. That has not been considered.

Mr. Miller. In regard to the compensation in kind, I should like to inquire if the mill owners assented to this being paid in this way, or if they went to the courts and got a decision in their favor.

President Saville. There were three different ways in which this thing was handled, — three different ways of looking at it by the mill owners. As I said in the beginning, all of the mill owners, practically, are very favorably disposed toward the city of Hartford. That was the basis on which the thing started. The largest mill owners, the ones that own a majority of the total water-power privilege on the Farmington River, signed an agreement with the city of Hartford that they would accept this method. That is, they signed it tentatively. They would accept it provisionally. They would withdraw their opposition. They did not, however, give up all of their rights to a future claim if they considered it necessary to make it. Another portion said they would not sign any agreement, but if they found they were not damaged as to the amount of water that was flowing, there would be no claims; and there probably will not be. The third portion, which was a very small minority, held the position that they would reserve all their rights in every way.

Mr. Fuller. Is the quality of the water of these three different reservoirs essentially the same?

President Saville. Essentially the same; yes, sir.

THE CONSTRUCTION OF NEPAUG DAM.

BY H. W. GRISWOLD, ASSISTANT ENGINEER.

[*Read September 13, 1917.*]

Contract No. 5, for the construction of a masonry dam and appurtenances, together with about one-half mile of highway in the towns of New Hartford and Canton, Conn., was awarded to Fred T. Ley & Co., Inc., of Springfield, Mass., in March, 1914, and was completed by them in July, 1917.

The dam was built largely of cyclopean masonry, with a maximum height above the surface of the rock of about 130 ft. and a length of 600 ft. In section, it is 20 ft. wide at the top, 90 ft. at the bottom, and is curved upstream to a radius of 390 ft. An overflow section was built in the center of the dam, the highway being carried over it on a series of 5 concrete arches, each having a span of 36 ft. The overflowing water falls down a series of steps into a pool lined with concrete, rubble masonry, and paving, at the base of the dam. The difference in elevation of the surface of the water in this pool and that in the reservoir is 100 ft. An inspection gallery, 7 ft. by 5 ft., entered from the lower gate chamber, runs parallel with the axis of the dam near the upstream face, and from this gallery seepage wells are carried down to rock and up to reservoir flow line.

For the transportation of material and supplies for construction, it was necessary to build a mile of standard-gage railroad up the Nepaug Ravine to the dam site from the New Hartford Branch of the New Haven Railroad. The grading for this spur was done with a $\frac{3}{4}$-yd. steam shovel, and a portable boiler and steam drill for the rock work. As soon as steel was laid on the spur, a commissary and bunk house of the usual type were built, and the construction of the cofferdams and flume begun.

The upper cofferdam was about 150 ft. upstream from the axis of the dam; the lower, 175 ft. downstream from the axis; and both were of the rock-filled crib type, with tongue and groove

sheet piling and toe fill on the river side. The flume was built along the foot of the west slope and was framed and planked as suggested on the contract drawings. This flume was removed as soon as the two central blocks of the dam were built above the river bed, and thereafter the river was diverted through a 10 by 10 ft. culvert in one of these blocks with a flume from the downstream face to below the lower cofferdam. In filling this culvert with concrete, after the dam was completed, the part between the upstream face and the inspection gallery was first poured, the water being carried around this section in a small by-pass which had been left in the concrete. This by-pass was next filled, and then the remaining section downstream from the inspection gallery was poured and the whole closure grouted to insure watertightness.

Excavation was started with the steam shovel as soon as grading for the spur track was finished, the excavated material being hauled by train to a spoil bank in a side valley about one quarter mile below the dam site. Earth at the top of the east slope was hauled by team to spoil bank below the dam, and material (largely sand) on the east slope was sluiced down to the steam shovel below with a fire hose. The same method was tried on the west slope, but was not successful, and the excavation there was completed with pick and shovel.

The underlying rock, a mica schist with numerous pegmatite dikes, had a dip of 45 degrees to the west, so that the east slope showed comparatively smooth ledge, while the rock on the west slope was very irregular. Just east of the river was a ridge of fairly sound rock, and between this and the foot of the west slope, under the bed of the river, was an area of hydrated mica schist, which had the unpleasant characteristic of disintegrating into a sort of blue mud, on exposure to the air in the presence of water.

Practically none of the dam is built on the original surface of the rock, it being necessary to excavate from 2 to 30 ft. before rock suitable for a foundation could be found. The upper part of this excavation was done by drilling and blasting, and the balance by barring and wedging. Spoil was handled by derricks and skips into cars.

A suitable foundation being secured, the next step was to make

a watertight cut-off in the rock, 10 to 20 ft. wide, near the upstream face, by forcing grout under pressure into the seams of the ledge. That a practically watertight cut-off was secured for the full length of the dam is shown by the very small leakage through the seepage wells with the reservoir within six feet of being full.

The method of laying out the work is of special interest, as nearly every surface of the dam is curved in at least one direction. The upper part of the downstream face of the non-overflow section is curved both vertically and horizontally. The method used, which worked out very successfully, was devised largely by Mr. G. W. Penfield, who was in charge of the field party, and consisted primarily of a dual system of rectangular and polar coördinates. The origin of polar coördinates was at the center of the sweep of the dam, the axis of which was curved to a radius of 390 ft., and over this point a 40-ft. tower for a transit station was built. A base line was run up the valley from this tower and a second base line, with concrete monuments at either end, was run at right angles to the first and tangent to the axis of the dam. From these base lines the rectangular coördinate system was extended as needed. All monuments were set by rectangular coördinates and checked by triangulation, the monuments at the ends of the east and west base line and the origin of polar coördinates forming the primary triangle. In laying out face forms, the expansion joint lines on either side were first given from the tower, and the intersection of the face form with these lines obtained by measuring a computed distance along the expansion joint lines from their intersection with an east and west rectangular coördinate line. Curve of form between expansion joints was given by ordinates from the eighth points of a chord, formed by pulling a line between the points on the expansion joints. Batter and radius boards were also used in checking and truing up forms.

In general, forms were built of 2-in. lagging, with 2 by 6 studs on 2-ft. centers, and 4 by 6 rangers. To save time in erection, lagging was cleated into panels 8, 10, and 12 ft. long. Forms were wired to plum stones or pins set in concrete.

The cement used for concrete work was tested at the mill and

on the job. Storage was provided for 60 cars or 10 000 bbls. Crushed trap rock was shipped from the quarry at Tariffville in bottom-dump, steel gondolas, from which the stone was dumped directly into the bins. Bin capacity was 2 000 cu. yd. stone and 1 000 cu. yd. sand. Sand was obtained from a glacial deposit in the valley used as a spoil bank, and stone for plums and heavy riprap was quarried in the same valley. Bowlders, picked out of the river with a locomotive crane, were also used for this purpose.

Concrete was mixed in two 1-yd. Ransome mixers, served by skip cars running in a tunnel under the bins. There was a wooden tower for each mixer, but both towers dumped into the same chute. Chutes were suspended from derrick guys, or cables put up for that purpose.

The method of placing concrete in the form was a new wrinkle which worked very successfully. It consisted of bringing the end of the main chute to a 30-ft. gin pole, fitted with two horizontal booms with a swinging radius of about 270 degrees. The upper boom was about 20 ft. long and the lower 10 ft. long. By suspending two 10-ft. sections of chute, one from the end of the main chute and the tip of the lower boom, and the other between the lower boom tip and a trolley running along the upper boom, concrete could be placed at any point within the swing of the upper boom. A 3-ft. square box was built around the gin pole, and the resulting hole in the concrete was filled up the next time concrete was poured in that block.

Before placing concrete on the rock foundation, the latter was washed perfectly clean with a hose stream, all loose rock removed, and the whole surface covered with grout, put on with a fire hose under about 80 lb. pressure. It was then plastered with mortar which was worked into all large cracks and holes.

The surface of each day's run of concrete was broomed or scraped with hoes the morning after it was laid; and, before fresh concrete was placed, it was thoroughly washed and broomed with grout. A crushed stone drain was laid between seepage wells to intercept seepage on a day's work joint. The expansion joint seepage wells were closed with concrete blocks, and the whole surface plastered with mortar; 1:3:6 concrete was then placed

in 1-ft. layers, beginning at the downstream face. Along the upstream face, a richer misture (1:3:5) was used for a width of about 3 ft. No drawboards were used. Plum stones were cleaned with a hose stream on the cars, and placed by derrick. In forms where chutes could not be used, concrete was placed with 2-yd. Haines buckets. About 375 cu. yd. was an average day's work with chutes, and bulkheads were built where necessary to give a depth of 6 to 8 ft. for a day's work.

In addition to the plums which stuck up above each lift, a key 6 in. deep by 3 ft. wide was left at the upstream face, and usually a section 4 to 6 ft. wide along the downstream face was left 6 in. higher than the rest of the run.

Sidewalks, the roofs of the gate chambers, and tops of parapet walls were trowel finished; spillway steps were floated, and sides of parapet walls and all panels were rough pointed. The downstream face of the non-overflow portion was sand blasted.

The cost of the work was approximately half a million dollars, and the following is a list of the principal items:

Earth excavation	35 000 cu. yd.
Rock excavation	20 000 cu. yd.
Refilling and embanking	17 000 cu. yd.
Cyclopean masonry	75 000 cu. yd.
Mass concrete	4 000 cu. yd.
Concrete surfaces finished	40 000 sq. ft.
Portland cement	80 000 bbl.
Large cast-iron pipe and special castings	40 tons
Metal for reinforcing concrete and for waterstops	100 000 lb.
Miscellaneous cast iron, wrought iron and steel	35 000 lb.

Discussion.

Mr. Frank L. Fuller. I should like to ask where the concrete was started from the rock, — whether the surface of the rock was leveled off, assuming that it was sound and in good condition but was not exactly level, — rounding, perhaps.

Mr. Griswold. I don't think there was a level place on the whole dam site.

Mr. Fuller. Well, was that leveled off into steps, or otherwise?

Mr. Griswold. It came out naturally in rough steps. It pitched down at about 45 degrees, and if you broke one lip and removed it, it left a step.

Mr. Fuller. So that but little hand work had to be done?

Mr. Griswold. In stepping the rock; yes, sir. There was quite a little hand work in cleaning out the cracks, and so forth.

Mr. Fuller. Did that leave a sound rock surface? Were these steps as you applied the concrete to them all sound and in good condition?

Mr. Griswold. As sound as could be expected, yes. That is, by testing with sledge hammers. Anything that was loose or could be broken off was removed.

GROUTING OF THE ROCK FOUNDATIONS OF THE DAMS OF THE ADDITIONAL WATER SUPPLY OF THE CITY OF HARTFORD.

BY J. E. GARRATT, OFFICE ENGINEER.

[*Read September 13, 1917.*]

To one of an inquiring and imaginative turn of mind, no part of the work connected with the building of Hartford's additional water supply is perhaps more interesting than the testing and grouting of the rock foundations on which its three large dams are located. At least the person actually performing the work has every opportunity to use all of such faculties that he may possess.

At each dam the main object of the testing and grouting of the rock foundation has been the same, — the making of one continuous section of the rock entirely tight to the passing of water, from end to end of the dam, and for a depth of 25 ft. into the rock. This "cut-off section," as it might be called, was located at the upstream edge of the Nepaug masonry dam and under a 10-ft. concrete apron on the upstream side of the concrete core walls of the Phelps Brook and the Richards Corner earth dams.

The problem of one tight section has been attacked in the same general manner at each dam. Two rows of drill holes, 25 ft. deep, with rows about 5 ft. apart, and with holes 15 ft. apart in the rows, and staggered, were first drilled. These holes were tested at various depths with water under pressure. The leakage was measured and careful observations were made of the location of seams, the interconnection of holes, the appearances of water at surface seams, etc. The amount of water pressure was always well above any which would be developed later by the water ponded against the dam. On the strength of this testing, the rock seams intersected by the hole could then be tightened by forcing grout into them.

If a hole was tight, no grouting of it could be done, of course, nor was it necessary. Such holes were poured full of mortar.

If a hole showed very small leakage, a thin grout could be used at once. If the leakage was considerable, a thick grout could be used to start with. If there were large leakages from a hole near its top, which indicated loose, seamy rock, grouting could be postponed until this rock was removed or until concrete was placed over the rock in the vicinity.

When this first group of holes had been completely grouted, other holes were drilled of various depths, depending upon the depth of leaky, seamy rock as shown by the first testing. These holes were located between the two rows of primary holes. They were then tested to show the results of the primary grouting. If they were tight, no further grouting was done. Depending upon the amount and the location of leakage and the amount of grout required to tighten such of these holes as needed grouting, other holes were then drilled, tested, and grouted, and this operation repeated until there was absolute certainty of the tightening of any seams of consequence in the area between the two rows of primary holes. As a rule, the grouting was completed with primary holes and secondary holes between. At places, however, where large seams or unusual conditions were encountered, as many as four sets of holes were drilled, tested, and grouted.

So much for the general scheme of the work. In the actual carrying out of the work at these dams, each case differed somewhat in the details, because of the character and the configuration of the rock.

At the Phelps Brook Dam (where the first grouting was done), the rock was a mica schist, set practically up on edge, without well marked bedding plane seams but with seamy areas striking across the dam at an angle of about 45 degrees to the center line. At the extreme southerly end of the dam the rock, as it originally laid, outcropped for about 200 ft. At the north end of this section there was a 30-ft., nearly vertical rock face. This rock wall was found, upon excavating, to continue 30 ft. more below the original ground surface. At its foot was a seam of green hydrated mica schist at a fault plane between the high rock at the south end of the dam and the low rock to the north. This low rock was found at a general level of about 30 ft. below the original ground. It continued for about 150 ft. to the north, where it quickly stepped

up to the original brook bed. From here towards the north was a ridge of apparently hard, sound, outcropping rock, which, 250 ft. on, suddenly disappeared again and was found to be about 20 ft. below the surface. From the north edge of this low-lying rock, of which there was about 70 ft., the rock rose quickly, outcropping for the most part, for a distance of 300 ft. to the north end of the dam. There were two deep excavations to the rock surface, one near the south end of the dam and one near the north end of the dam. Between them was a ridge of high, hard rock which originally outcropped. At each end of the dam the rock was high and also outcropped.

Grouting was started at the Phelps Brook Dam in the late summer of 1914 and was completed in the spring of 1916. The first grouting was done at the deep excavation near the south end of the dam. No surface rock was removed, as it was smooth and hard and apparently sound. Tests of these holes showed no large deep-seated leakage, although the upper portions of the rock were found to be quite full of seams. Attempts to grout these holes with 60-lb. air pressure loosened portions of the surface rock in places, and the grouting of the primary holes was completed only after the concrete apron was placed over all of the rock in which they were drilled. Even then comparatively large quantities of grout were wasted in efforts to stop surface leakage and blow-outs. When secondary holes were next drilled and tested in this location it was found that there was a large, deep-seated seam which took water away in considerable quantity and through which the same water came back under several feet of head. Large quantities of grout were required to tighten this seam, and none of the grout appeared at points other than adjacent grout holes. Proof holes next drilled still showed some leakage, but only small and deep down. They were grouted with but little grout and the rock was considered properly tightened.

At the southerly end of this deep excavation there was an almost vertical rock wall. At the foot of this wall was a 30-ft. seam of soft green hydrated mica schist. There had been a fault or a slip in the rock at this point at some time. Holes in this hydrated rock were practically tight, but the rock was so weak when not confined that grout pipes could not be held in the tops of the

holes, and grouting was completed only after concrete was placed over the rock.

As it was the natural desire of the contractor to fill both deep excavations before the end of the first season, the next grouting was in the excavation at the north end of the dam. Although the rock in this hole was a seam of apparently none too sound rock, it was thought that it would be cheaper to tighten it by grouting than to remove it. Attempts to tighten it, however, before any concrete apron was placed, loosened several feet of the surface rock, and the grouting was abandoned, while five to seven feet of the top poor rock were removed. Concrete was then placed over the remaining rock and grouting was completed through holes drilled into the rock through this concrete apron.

The high ridge of rock between these two holes was grouted the following spring and summer before any concrete was placed over it. Many of the holes drilled in it were tight throughout. From one hole in this rock, grout carried 40 ft. along a seam parallel to the center line of the dam and outflowed in the bottom of a 10-ft. trench in the rock.

The rock at the northerly end of the dam was, for the most part, sound and good and was grouted with little difficulty. At the extreme northerly end, the rock for a distance of 100 ft. was tight and only one row of drill holes, 15 ft. deep, was put down to prove this area.

No great difficulties were encountered at the south end of the deep southerly excavation in grouting the 60-ft. vertical rock wall there. Inclined holes 25 ft. deep were drilled in the rock face as the concrete core wall was brought up in 5-ft. lifts. These holes were grouted either before or after concrete was placed over the tops of them, depending upon whether there were not or were large seams near their tops.

South of this vertical rock wall the high rock at the south end of the dam was quite seamy near the surface. It was, however, grouted with no great amount of trouble and, generally, before concrete was placed over the holes. In the rock at the top of certain of them, to be sure, blow-outs occurred and blocks of rock a yard or more were loosened during the grouting attempts, but these loosened blocks were removed and the grouting then completed.

At the Nepaug Dam the rock was a mica schist with regular and marked laminæ dipping 45 degrees to the west and striking at right angles to the center line of the dam. Consequently the rock on the east side of the dam presented steep, smooth faces, that in the center was, in section parallel to the dam, saw-toothed, and that on the west side presented the ends of the laminæ only.

At the center section, considerable surface rock was removed at once before any grout holes were drilled. The rock was then tightened without much difficulty and with seldom more than secondary holes. At the foot of the steep slope at the west side of the valley there was a seam of hydrated mica schist, similar to that encountered at the south end of the Phelps Brook Dam, only black instead of green. The rock on either side of this seam was loose and seamy and was excavated to a maximum depth of 35 ft. In the sound rock finally reached, holes were drilled to thoroughly explore and cover this zone of fault and contact. The seam of hydrated rock was then quickly covered with concrete and the grouting was done through this concrete.

On the steep slope at the east side of the valley, grout holes were drilled for the most part in the hard, smooth, original surface of the rock. At several places the first grouting loosened large thin slabs of this surface rock, which were then removed. Below 5 to 10 ft. down, however, this rock was tight.

On the steep slope at the west side of the valley, explorations with a diamond drill hole and with a few grout holes showed that the surface rock was loose and seamy. So large amounts of rock were removed in places. Even then grouting could not be done until concrete had been placed over the rock. This was not due to any serious weakness in the final rock, but to the fact that the rock was set well up on edge and the grouting pressure would blow out through the seams at the top of the holes. Below a few feet down the rock was generally tight, and, with a mat of concrete to hold the grouting pressure, it was easily grouted. Several springs in the rock were encountered. These were piped through the concrete and grouted as any other grout hole.

At the East Branch compensating reservoir, Richards Corner Dam, in addition to making a tight section under the upstream edge of the core wall, this section is to be continued under the

spillway section at the westerly end of the dam. Also where the diversion conduit passed through the core wall, the rock which was to underlie the conduit was grouted for a distance of about 40 ft. above and below the core wall through three rows of holes 25 ft. deep. One row of holes was located under the center line of the conduit and one row 10 ft on either side of this one, which brought them near the outside edge of the conduit invert. No concentrated effort to tighten completely this whole section was made. The object of the grouting was to discover and tighten any seams of considerable size or extent which later might cause upward pressure on the conduit. The rock under the conduit was found to be a mica schist with intrusions of pegmatite dikes striking southeast-northwest about 45 degrees to the axis of the dam, which runs east and west, and dipping about 60 degrees to the southwest. In those areas where dikes were located, of which there were three, there were often large leakages and interconnections of holes 20 ft. apart.

In the area just upstream from the core wall, which was a portion of the section to be thoroughly tightened, efforts were concentrated, secondary and then tertiary holes were drilled, tested, and grouted, and the section surely tightened.

West of the diversion conduit, which is near the easterly end of the dam, the rock slopes downward very steeply. For a distance of about 60 ft. this rock was poor mica schist. Holes were drilled in it to test it out. Tests showed that it was quite weak and seamy at the top. Attempts were made to grout all of these holes with the idea, principally, of loosening the poor surface rock so that it could be removed easily. The grouting of them was completed some time later after the core wall had been brought up to the elevation of the rock here.

Working westerly from this section of poor rock, the rock was grouted in 30-ft. sections as it was uncovered and prepared for concrete. Drilling and testing was, of course, done before any concrete was placed over the section, but grouting was generally done after the concrete apron was placed. This was not because the rock was poor, but because water and slipping banks made it desirable to cover the rock as soon as it was once properly cleaned. About 200 ft. from the conduit the rock changed from

a mica schist to a hard gneiss. Holes in this gneiss were often tight. Near the zone of contact between schist and gneiss an open seam about 3 in. wide, nearly horizontal, and 15 to 20 ft. down, was discovered. This could be tightened only by pumping grout into it until it flowed freely from surface outlets and then allowing the grout to set in the wide seam. Other than this no great difficulties have been encountered in any of the grouting work here. The grouting is not completed.

Grouting Equipment.

At each of the three dams a Ransome Canniff grout mixer of 4.5 cu. ft. capacity was used for the grouting work. This machine mixes and discharges the grout by air pressure. At the Phelps Brook Dam a gasoline-driven air compressor was first used. This furnished an abundant air supply at pressures up to 80 lb. *when it worked.* But it was very likely to stop work in the midst of the operations of grouting an important hole. Mixer and connections would then plug, and often an hour would be lost in cleaning them out. More serious than this, from the grouting point of view, was the feeling that the grout already in the hole might have settled into the bottom and plugged there, thereby preventing additional grout from getting into seams not completely tightened. A small steam-driven Westinghouse air pump with a storage tank of 20 cu. ft. capacity was later substituted for this. This could furnish 60 lb. pressure at the most and could not be recommended for the work. At the Nepaug Dam a large steam-driven horizontal air compressor furnished an abundant air supply always at pressures up to 100 lb. At the Richards Corner Dam a large steam-driven Westinghouse air pump with storage tank of about 100 cu. ft. capacity furnished an abundant air supply at any pressure up to 80 or 90 lb. (provided it was furnished with the necessary supply of steam).

Grouting was done for the most part through pipes cemented into the tops of the holes. At the Phelps Brook Dam $1\frac{1}{4}$-in. pipes were used, and $1\frac{1}{4}$-in. flexible rubber hose connected mixer and grout pipes. This hose often plugged when holes were nearly tightened and the flow of grout became small. So a blow-off valve was attached to the end of the rubber hose. At the Nepaug

and Richards Corner dams, as a result of the troubles experienced at the Phelps Brook work, a 2-in. flexible grout hose was obtained and 2-in. pipes were used in the holes there. With grout pipes cemented into the holes it was always necessary to wait at least a day before putting pressure into the hole and often, during cold weather, pipes were blown out of holes after having been cemented in for two or three days. So, early in the Nepaug Dam operations, a grouting plug was rigged up. This consisted of a 2-in. pipe on one end of which was a rubber plug which could be expanded and tightened in the top of the grout holes. All holes which could be grouted before concrete was placed over them or which were not too irregular at the top were grouted thereafter through this grouting plug.

As found from our experience then, the most satisfactory accessories for a Ransome Canniff grout mixer are an abundant air supply from any source which is surely continuous, a 2-in. flexible pressure hose in 25-ft. sections for ease in cleaning if necessary; at the end of the hose a 2-in. tee with blow-off stopcock (no gate valve is satisfactory for this) on one outlet and a 2-in. union on the other for connection to a 2-in. grouting plug or to a 2-in. grout pipe cemented into the grout hole.

Practical Points in Actual Grouting Operations.

Following is a general idea of the consistency of the grout used in our grouting operations.

1. With small leakage from a hole, say 0.5 cu. ft. per minute or less, in order that grout will carry along small seams, one bag of cement is added to a mixer full of water, which gives a grout of about 1 : 4.

2. With moderate leakage, say 0.5 to 1.0 cu. ft. per minute, a grout of 1 : 2.5 is used.

3. With large leakage, say 1 to 2 cu. ft. per minute, a 1 : 2 grout is used for three or four charges and then sand in increasing amounts is added in efforts to plug the seam.

In poor rock, care must be taken to close off the mixer as soon as a charge is emptied, so that air will not get into the hole and into the rock seams and blow up the surface rock.

When grouting holes with small leakage, the blow-off valve at

the hole end of the hose should be opened at least every three minutes to prevent the grout from settling and plugging the mixer or hose.

With sand in the grout, the air must be kept boiling up through the grout until just the moment that the charge is turned into the hole.

Consequently, none but the best intelligent labor should be used on this work, as delays due to plugged hose and mixer and surface blow-outs are costly and prevent the most effective grouting of the holes.

If large surface blow-outs occur, it is futile to continue the attempt to grout a hole to refusal. If no concrete has been placed over the rock it has been found best to put the air pressure into the hole, loosen the top rock in this way, and then remove it. If concrete has been placed over the rock, or if a seam is well down but large and open, continue grouting with a thick sandy grout until the seam is surely well filled with grout and then leave the grouting for a day or so to give the grout a chance to set in the seam. Repeat this operation until the hole is tightened. Secondary holes then are quite essential because the large seam may have so vented the pressure originally that other smaller seams were not filled with the grout.

Suggested Method of Grouting and Proving the Rock Foundation of a Masonry Dam.

It seems to the writer that the following would be the most satisfactory arrangement of holes and method of procedure for the tightening and proving of the rock foundation of a masonry dam after all loose surface rock had been removed.

1. Drill two rows of primary holes 7 ft. apart with holes 15 ft. apart in each row and staggered, the upstream one of these rows to be located just under the upstream face of the dam. Test and grout these holes.

2. Drill, test, and grout secondary holes as needed between these.

3. Drill, test, and grout tertiary and even quarternary holes if needed to finally prove the grouting

4. After this grouting is finished, section by section if the work is so carried on, drill vent holes about 15 ft. back of the upstream

face of the dam, spaced 10 ft. apart, of such depth as the testing of the grout holes shows to be necessary, and carried by pipe up into the inspection gallery of the dam to be observed, tested, and grouted or treated as needs be after the water is ponded against the dam.

5. If there is to be considerable head of water on the rock foundation due to the water standing on the downstream side of the dam, in so far as is reasonably possible by the removal of loose rock, by drilling and grouting of holes, or by placing of vent pipes at outflows to be grouted later, make tight the rest of the rock bottom below the elevation to which water will stand on the downstream side.

6. Above the elevation to which water will stand on the downstream side, unless springs under pressure are encountered, make no attempt to tighten the rock bottom downstream from the upstream grouted section.

Discussion.

Mr. Frank L. Fuller. I should like to ask if this grout was put down through the pipes, and were the pipes raised as the grouting continued?

Mr. Garratt. Yes, when it was necessary. Holes were drilled into the rock 25 ft., and into the tops of those holes a pipe extending below the surface about a foot was cemented, so that the rubber hose from the mixer could be fastened to the pipe and the grout forced into the hole.

Mr. Harold K. Barrows. Was that work done by the contractor at the various dams or in some other way?

Mr. Garratt. The labor was furnished by the contractor, but we always had a representative there. I myself did a good deal of the directing.

Mr. Barrows. I want to ask further how it was paid for, — whether as a matter of time or how?

Mr. Garratt. No. It was paid for by items. There were various items of connections for grouting, cubic yards of grout forced into the hole, — of the pipe used in the hole. The cement was paid for as a separate item.

CARE AND OPERATION OF MECHANICAL RAPID SAND FILTRATION PLANT.

BY JOHN W. GAITENBY, SUPERINTENDENT FILTRATION PLANT, EVANSTON, ILL.

[*Read September 12, 1917.*]

Mr. President and Members of the New England Water Works Association, — At the request of your President, Mr. Saville, I have prepared a short, informal paper on the care and operation of a rapid sand filtration plant.

The plant of which I have the honor of being superintendent is located at Evanston, Ill., and is a municipally owned plant of 12 million gallons' daily capacity per twenty-four hours. This plant was installed for the city by the Norwood Engineering Company of Florence, Mass., from plans and specifications prepared by George W. Fuller, of New York, and Langdon Pearse, of Chicago. The contract was let in 1913 and completed in 1914.

The plant consists of six filter beds, each having a filtering area of 738 sq. ft., with a filtering capacity of 2 million gallons each per twenty-four hours, or at the rate of 125 million gallons per acre per day. The source of supply is from Lake Michigan, through an intake pipe extending about $1\frac{1}{16}$ miles out into the lake, but still within the range of drift for the sewage of Evanston and Wilmette, a town to the north, the greater part of which is discharged into the lake.

During the five years previous to the installation of the filter plant, the average death-rate in Evanston per 100 000 was 26.6. Since the installation of the filter plant, the death-rate has been greatly reduced, and since 1916 there is no record of any deaths from typhoid fever, although the raw lake water has shown indications of B. coli in practically all samples taken before treatment.

Care and Operation.

To operate a filter plant efficiently, a certain portion of the work should follow a definite schedule. The operations which can generally be so arranged are the regularity of making tests, the proper preparation of the coagulant solutions, inspection of the plant, especially the condition of the filters, and the washing of same.

The first and most important matter to be considered is the necessity of having good, reliable help at all times, who can keep correct records of all operations and results, and who are able to figure or compute the different amount of chemical fed to each million gallon or part thereof that is being pumped to the plant at all times, for in some plants the pumpage is uniform throughout the twenty-four hours, while with others, as in our case, it varies from 3 to 17 million gallon rate throughout the twenty-four hours. At our plant, the amount of water pumped to the filter is registered by means of a Venturi meter, and readings are taken each hour; and whenever the engineer at the pumping station wishes to change the rate of pumpage he notifies the operator at the plant, and he immediately changes the chemical feed and filter rate controllers accordingly. Lake Michigan water varies so little that we are able to run practically the same amount of coagulant at all times.

Care of Sand in the Beds.

Each bed is inspected during the washing, to see that the wash is uniform, and once a week the water is drawn off of the filters entirely and the sand examined. If patches of dirty sand, or mud balls, are found, the beds are raked up and down with a heavy double-tooth rake made for that purpose, allowing a small amount of wash water to be applied to the filters during this raking process. After this raking process, the wash water is turned on for about three times its ordinary washing period, so as to carry all dirt over into the wash gutters. The filter is then drained again for inspection and is sterilized by sprinkling with a strong solution of chloride of lime. Both the walls and the sand are allowed to stand in this condition a couple of hours, when it is washed again to remove the chloride of lime solution.

Rate Controllers.

The rate controllers are examined at frequent intervals, to see that they check up with the master controller, and each bed is measured to see that they are uniform and check with the rate controller.

All of these different operations are registered on specially prepared sheets or charts for that purpose, which are kept for future reference and which are transferred to the monthly operating sheets.

Loss of Head Gages.

The loss of head gages are read every hour and recorded. When the loss of head reaches 11 ft., the filters are washed in the usual manner by closing the influent valve and allowing the water to filter or lower in the beds to a level with the tops of the sewer gutters. Then the effluent valve is shut, the sewer valve opened, and the wash-water valve is opened slowly and gradually until the required amount of wash water is being obtained. The exact time required for washing the filters is recorded; also the exact amount of wash water is recorded. The influent valve is then opened partially, and the filter bed is allowed to fill up to the same level as the other filters and the bed allowed to stand for a few minutes before being put on to the filtering process again.

High-Velocity Wash.

We use at our plant what is known as the "high-velocity wash." In other words, we use 15 gal. of filtered water per square foot per minute for washing the filters, and while this high rate of wash water keeps the sand in good condition, I do not think that it is any better than the normal rate of washing combined with air. I have had considerable experience, both with the normal rate of washing with the combined air wash and with the high rate of wash, and I have found that the sand bed is agitated much more thoroughly and kept in a very much cleaner condition with the combined water-and-air wash than with the high-velocity wash, besides saving a very large amount of filtered water in this washing process.

Tests.

Each day the water in the settling basins and on the filter is inspected to ascertain the condition of the floc or aluminum hydrate, and the turbidity is taken of the raw and settled water, also the temperature. We also take samples of the raw, settled, filtered, and sterilized water for bacteriological analysis and plate samples of each on agar and gelatine plates, and incubate same for forty-eight hours at 20 degrees C. We also plate these samples on litmus agar plates for twenty-four hours at 37.5 degrees C., for acid colonies and pathogenic type; also tube samples of each water in lactose bouillon at 37.5 degrees C. for twenty-four hours for gas formation. The results of these tests are recorded on index cards printed for that purpose and transferred to the monthly report sheets.

The entire plant is kept clean by sweeping and mopping, and the woodwork and iron work are painted so as to keep same in a clean and sanitary condition at all times. The plant is opened for inspection to the public at all times.

The bacterial efficiency of the plant is very high, averaging, for the year 1916, 99.86 per cent.

The settling basins are cleaned by draining through valves located in the bottom of same for that purpose, and are washed out with a fire hose every six weeks.

Cost to Filter Water.

During the year 1915 we filtered 2 325 400 000 gal., or an average of 6 371 000 gal. per day. Of this amount we used 85 589 000 to wash the filters, or 3.68 per cent., at a total cost of $9 203.00, or $3.96 per million.

Average amount of alum used	.72 gr. per gal.
Average amount of hypo used	3.5 lb. per million

This total cost per million gallons includes salaries, chemicals, supplies, light and power, etc., divided as follows:

Chemicals	30 per cent.
Salaries	55 per cent.
Light, power, supplies	15 per cent.

Hypo	3c. per lb.
Alum	1c. per lb.

During 1916 we filtered 2 495 040 000 gal., or an average of 6 808 000 gal. per day, at a total cost of $9 587.92, or $3.80 per million, divided as follows:

Chemicals	35 per cent.
Salaries	53 per cent.
Light, power, supplies	12 per cent.

Of this amount of water, 72 865 000 gal., or 2.92 per cent., was used to wash the filters.

Hypo, 7c. per lb. 4 lb. per million gallons.
Alum, 1.28c. per lb. Average amount used, .67 gr
Total number of men employed, 5.

State Water Survey.

Department of Chemistry, University of Illinois.

Urbana, Ill., May 25, 1917.

Laboratory No. 37147.

Report of the Sanitary Analysis of Water.

Sent by John Gaitenby.
Town: Evanston.
Source of water: Raw water.

(Amounts are stated in parts per million.)

Turbidity, 20. Color, 5. Odor, 0.

Residue on evaporation	180.	Bacteria per cc.:	
Chlorine in chlorides	5.	Gelatine	60
Oxygen consumed	3.6	Agar	80
Ammonia nitrogen	.022	Gas Formers:	
Albuminoid nitrogen	.102	10 ccm	1+
Nitrite nitrogen	.000	1.0 ccm	2−
Nitrate nitrogen	.64	0.1 ccm	1+1−
Alkalinity, phenolphthalein			
Alkalinity, methyl orange	122.	Indol	

The analysis indicates that the raw water had received some contamination. It should not be used for drinking purposes unless properly treated.

ANB/R

See enclosed circular.

EDWARD BARTOW,
Director State Water Survey.

A. N. BENNETT,
Chemist.

37147

STATE WATER SURVEY.

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF ILLINOIS.

URBANA, ILL., May 25, 1917.

LABORATORY NO. 37148.

Report of the Sanitary Analysis of Water.

Sent by John Gaitenby.
Town: Evanston.
Source of water: Filtered water.

(Amounts are stated in parts per million.)

Turbidity, 0. Color, 0. Odor, 0.			
Residue on evaporation	150.	Bacteria per cc.:	
Chlorine in chlorides	5.	Gelatine	1
Oxygen consumed	3.3	Agar	12
Amomnia nitrogen	.010	Gas Formers:	
Albuminoid nitrogen	.056	10 ccm	1 —
Nitrite nitrogen	.000	1.0 ccm	2 —
Nitrate nitrogen	.24	0.1 ccm	2 —
Alkalinity, phenolphthalein			
Alkalinity, methyl orange	118.	Indol	

The analysis shows that the water had been properly treated and that it was in excellent sanitary condition and suitable for drinking purposes at the time of sampling.

ANB/R

See enclosed circular.

EDWARD BARTOW,
Director State Water Survey.

A. N. BENNETT,
Chemist.

37148

NOTE. There are on file at the Association rooms, Tremont Temple, relating to Evanston, Ill., filtration plant, and accompanying above paper, the following:

Paper — "The Rapid Filter Plant at Evanston, Ill.," by Langdon Pearse; read before M. W. S. E., 1913.

Report, by Consulting Engineers Walter W. Jackson and Langdon Pearse, to City of Evanston, Ill.

Blank form for laboratory report on samples.

Blank form for chemical and general records.

Blank form for daily filter report.

Tables — Monthly summary of operation and results for June, July, and August, 1917.

Discussion.

Mr. Harold C. Stevens. I should like to ask Mr. Gaitenby's opinion as to how the air acts in producing the good effect. Some people seem to think the whole bed is affected, the sand tumbled about, loosened. It seems to me, as the air leaves the strainers, it finds certain passages and continues to flow along those passages, disturbing the sand on the surface.

Mr. Gaitenby. I don't know; I don't think they do. They might possibly do such a thing on a plant where an air system had been in for some time and some of the air openings plugged or spaced too far apart. But if they use slots in their air tubes the bed will look as though the water was boiling, — it is rolling all over. And in a plant where the air is sufficient, and the slots in the tubes, or any other device, are equally spaced, and all of the same size, none plugged, you ought to get just as much air one place as another.

Mr. Stevens. In some places I know you can, for we have places where the air is coming up. There are little craters all over the bed, — springs.

Mr. Gaitenby. You will note that there is sediment of some kind that might get into these tubes and plug up some of the slots, and that would of course force the air out through a very few. That might happen. I have known instances — not necessarily on municipal plants, but on industrial plants — where it would throw the gravel up, there was so much air in some sections of bed and in other sections of the bed there was none, the pipes were plugged. The main air pipe was filled with sand or gravel.

Mr. Stevens. I remember one filter where it showed uniformly over the whole bed. The strainers were spaced about six inches, and the air reflected downward.

Mr. Gaitenby. I believe all filter plants that use air systems do not work the same. I think a good thing to do would be to set the safety valve on your air compressor, whatever you use, to a certain pressure for that plant. It might be all right on this plant and no good on the next plant. You have to use your own judgment. Where it might take five pounds pressure and a certain number of cubic feet of air to wash one bed, at another

bed it might not take nearly as much. Air, to be effective in washing filters in connection with wash water, should be a separate system so as to use both wash water and air through separate systems, and the openings for air should be very small holes or slots spaced not more than three inches apart all over the area of the filter bed. This air system works best if placed above the gravel layers in the beds. In this position it does not disturb or misplace the gravel.

SOME ASPECTS OF STREAM POLLUTION IN CONNECTICUT.

BY J. FREDERICK JACKSON, DIRECTOR BUREAU OF SANITARY ENGINEERING OF THE DEPARTMENT OF HEALTH, STATE OF CONNECTICUT.

[*Read September 13, 1917.*]

The question of stream pollution in Connecticut began to attract public attention about the middle of the nineteenth century, coincident with the construction of sewerage systems by towns and municipalities. Undoubtedly there was more or less contamination by mill towns prior to that time, but its extent and character was not such as to attract general notice. The agitation was caused, as examination of the court records of those days will show, by the attempt of individual riparian owners on non-navigable streams to assert their rights to have the water of a stream covering their lands flow in its accustomed manner.

With the growth of cities and increase in number and size of industrial plants, the condition of the streams — both navigable and non-navigable — grew rapidly worse, and we find the people of the state as a whole seeking to maintain their rights against powerful municipalities and large industrial corporations. This movement has been a slow one because it is axiomatic that the people as a whole move less easily and quickly than the individual. But it has been a very persistent movement, and its force was evident when the General Assembly in 1913 instructed the state board of health to investigate the pollution of the waters of the state, both tidal and inland, and recommend means for terminating it. This the state board did, and their report to the General Assembly of 1915 was largely instrumental in forcing the passage of the present statutes relating to sewage disposal and the protection of water and ice supplies. In the meantime, municipalities and privately owned water companies had abandoned the use of the larger rivers as sources of supply, and sought others

remote from centers of population and less liable to contamination. It may be of interest to reflect that we might to-day be drinking water of the Connecticut and Housatonic properly filtered if the application of Wanklyn and Franklin's discovery of method of determining organic matter to the filters at London had not been so disappointing in the small amount of organic matter removed, causing that city to seek unpolluted sources, or if the significance of the germ theory in its relation to water purification had been fully understood.

To me the thought of the economic waste of millions of gallons rushing by the very doors of some of our larger cities — water generally satisfactory in most of its physical characteristics, and with modern methods of filtration entirely so, from the standpoint of health — is to some degree depressing. No water-works' official, no matter how ideal his source of supply may be, feels absolutely safe from accidental contamination, and all the trouble and expense of bringing water from distant sources will in most cases not avoid the necessity of finally filtering the water.

Engineers are prone to consider that half the solution of any problem lies in separating it into its component parts. In the study of any river of considerable magnitude, the conditions affecting its pollution are so varied and complex that their segregation is very difficult. How much greater must this be when we consider all the rivers and inland waters of a state like Connecticut. The watersheds of the Connecticut, Housatonic, and Thames alone comprise about 71 per cent. of the total area, and the lakes, swamp, and salt marsh total about 145 square miles. The estimated population is 1 238 723, the density per square mile being 231.3; only three states in the Union exceed this. About 89 per cent. dwells in cities and towns and 23 per cent. is employed in manufacturing. In value of manufactured products she ranked twelfth in 1909, producing $490 272 000 worth, of which the materials cost $257 259 000, leaving the net wealth created $233 013 000.

Studies of pollution of a stream may be under any of the following forms: source of water supply, disposal of storm water, shipping, water used for industrial processes, fishing, boating, bathing, camping, disposal of refuse.

There are 105 water companies located in 99 towns out of 168 towns of the state. Twenty-two of these are municipal and 83 private. In addition, there are 6 institutional supplies. None of the towns take their supply from the larger rivers. The larger companies are, and have been for some years, protecting their source of supply by acquiring land, by patrol, and by laboratory control. Eleven have some method of filtration and 8 others disinfect.

Most of the towns dispose of storm water into the nearest water-course. Thirty-eight towns have sewerage systems and 17 treat their sewage. The different methods of treatment are 7 sand filtration, 2 sand and broad irrigation, 3 septic tanks, 1 septic tank with contact beds, 2 digestion chambers followed by sand filtration, 2 Imhoff tanks with disinfection.

Shipping to any considerable extent is restricted to the Thames, Connecticut, Quinnipiac, and Housatonic.

All manufacturers located on streams use them unrestrictedly in processes of manufacturing, subject only to riparian rights of owners above or below. Very often the entire flow of a river is diverted to pass through the factory, and is discharged below in very bad condition.

Fishing as an industry has practically disappeared. The value of the oyster industry in 1905 was $2 809 839; in 1910 it had decreased to $1 885 494; the number of shad taken in Connecticut River in 1903 was 176 085; in 1913, it was 52 053; and, except for the efforts of Fish and Game Commissions, there would be but little fishing left for the sportsman.

Camping, bathing, and boating, with the growth in population, shorter hours of labor, and general observance of Saturday half-holiday, is increasing every year, and in particular is this so along the shore front. The bathing beach which is not polluted is an exception.

Disposal of refuse only affects the streams when public dumps abut the shore front.

The problem is to study, classify, and correlate the different uses of our tidal and inland waters so as to cause a minimum of inconvenience to our growing municipalities and industries and still safeguard and preserve the rights of the general public.

The first and most important of these is preservation of public health. The wealth of a nation lies in the health of its citizens. Little pride is to be taken in populous cities and thriving factories if peopled and operated by a sickly and anemic race. The phrase "public health" is purchasable, has become a household phrase, and where it is concerned all other uses of a stream menacing it must be eliminated.

This result being assured, the further study should consider each stream in its relation to the public welfare, giving due weight to economic values of the interests affected. Absolute prohibition of their use for the disposal of wastes is rarely wise. Restricted use to conform to ever-increasing standards of public decency is both possible and desirable. This result can only be obtained through coöperation. No longer is there such a marked tendency on the part of municipalities to put off the installation of sewage treatment works awaiting the perfection of some undeveloped method to furnish a universal solution of waste disposal. No longer is the attitude of forward-looking men, engaged in manufacturing, strongly antagonistic to all legislation regulating the use of streams in disposal of industrial wastes. They have realized that something has to be done to preserve in our streams even a moderate degree of purity, and are giving to the question the same intensive study which has brought them success in their own particular field. While the problem is most complicated, certain fundamentals have been laid down in at least two instances which we may safely take for our guidance. In their report to the Great Lakes International Pure Water Association and the National Association for Preventing Pollution of Rivers and Waterways, in 1911, the committee formulated these general principles.

Streams from which Water Supplies are Taken without Purification. Such streams should not receive any fecal matter, sewage, sewage effluent, or wastes that will render the water a menace to health or otherwise impair its natural quality.

Streams from which Water Supplies are Purified. Such streams should not receive fecal matter, sewage, sewage effluent, or waste matters in such quantities that the contamination of the water at any water-works intake would put an unreasonable burden

upon the purification works or in quantities sufficient to produce the conditions referred to in the next paragraph.

Streams Not Used for Water Supply. Such streams may receive sewage wherever and in such quantities that its entrance will not sensibly offend decency in the reasonable public use of the stream, or cause interference with navigation or with valuable fish industries or the ice industry. Where this cannot be done, the sewage or wastes should receive such treatment before discharge as to bring the effluent within this rule, due regard being given to the relative cost of the processes required and the benefits to be derived.

Large Lakes from which Water Supplies are Not Filtered. Such lakes should not receive fecal matter, sewage, sewage effluents, or other waste matters in such amounts or at such places that the water reaching the intake would be contaminated to the extent that an unreasonable load would be placed upon the filter, or in quantities sufficient to produce the conditions referred to in the next paragraph.

Lakes Not Used for Water Supply, Harbors and Estuaries. Such bodies of water may receive sewage if discharged in such a manner as to be quickly and thoroughly diluted so that its entrance will not sensibly offend decency in the reasonable use of the water, or interfere with navigation. Where this cannot be done, sewage should receive such treatment before discharge as to bring the effluent within this rule, due regard being given to the relative cost of the processes required and the benefits to be derived.

And again, in the report of the Committee on Sanitary Control of Waterways, to the Sanitary Engineering Section of the American Public Health Association, in 1916, the committee, after several years of careful study, recommend the adoption of — (1) There shall be no objectionable deposits at any point in a waterway as a result of sewage or other wastes discharged therein; (2) there shall be no local nuisance created at or in the vicinity of any sewage or industrial wastes outfall, arising from excessive turbidity or the production of odors; (3) there shall be no general nuisance created in a waterway due to excessive turbidity or to odors, as a result of sewage or other wastes discharged therein; (4) there shall be no interference with or undue burden upon

mechanical operation or bacterial efficiency of water purification plants procuring their raw water from a waterway; (5) there shall be no active (potentially dangerous) bacterial contamination or gross pollution of properly located and authorized shellfish beds; (6) there shall be no active (potentially dangerous) bacterial contamination or gross pollution of properly located and authorized bathing beaches and other bathing places.

Both of these reports are admirable and the work of men foremost in sanitary knowledge in the country. It is interesting to observe the change in five years as evidenced in these two reports, and to note that it is not in the line of less restrictions.

Public sentiment is demanding, and will continue to demand, greater rather than less restrictive regulation of pollution of our streams; and while we may never expect to see the rivers of Connecticut restored to their pristine condition, we may confidently hope that the more beautiful stretches will again be used for boating and fishing, that flocks and herds will pasture once more on many barren hillsides, and her harbors and estuaries be free from gross pollution so destructive of fish life and restrictive of bathing, — all accomplished through the harmonious efforts of state, municipal, and industrial interests, working hand in hand.

SOME OPERATING PROBLEMS OF A SMALL WATER DEPARTMENT.

BY HOMER R. TURNER, SUPERINTENDENT AND ENGINEER, THE WINDSOR FIRE DISTRICT.

[*Read September 12, 1917.*]

The town of Windsor is situated on the west side of the Connecticut River, six miles north of Hartford. There is a small amount of manufacturing, the balance of the town being devoted to farming and a suburban residential section for the city of Hartford. The water supply is obtained from Mill Brook, two and one-quarter miles west of the populated district known as Windsor Center, and is pumped from an impounding reservoir on that stream to the standpipe situated on Cook Hill, one mile west of the district. From there it flows by gravity through two independant supply mains to the distribution system.

The town of Windsor, after negotiations in 1910, had refused to purchase the plant of the Windsor Water Company, a private corporation. In 1915, the thickly populated part of the town obtained a charter from the legislature incorporating the Windsor Fire District, with authority to purchase the Windsor Water Company. As a result, the Windsor Water Company came under municipal ownership and plans were immediately made for improving and strengthening the system. Contracts were awarded for new pumping equipment, a steel standpipe, and extensions and strengthening of the distribution systems, including the installation of fire hydrants throughout the district.

Water Purification.

The impounding reservoir, known as Barber's Pond, has a storage capacity of 15½ million gallons, and has a watershed of approximately two square miles. A large part of this drainage area is devoted to tobacco raising, there being several large plantations on the watershed.

In January, 1917, during freshet conditions, positive tests for colon bacillus were first obtained. Recurrence of this colon test proved the necessity of treatment of the water before pumping into the distribution system. In July, 1917, the Board of Commissioners of the district authorized the installation of a liquid chlorine disinfection plant. Under the direction of Mr. James A. Newlands, chemist for the water department, the writer immediately installed a solution feed, manual controlled, chlorinator, manufactured by the Wallace & Tiernan Company. This chlorinator is connected to the suction main of the pumps, and is housed in a separate building about 30 ft. from the pumping station. The water is being treated with chlorine at the rate of six-tenths parts per million. The comparative tests of raw and treated water have shown a reduction in bacteria of 85 per cent. and a reduction in colon bacillus of 100 per cent.

During July of this year disagreeable odors were noticed in the water, and an investigation showed that large masses of spirogyra had become caught on fixed growths in the shallower portion of the reservoir bottom. On decomposing, this had produced the odors noticed in the water. The condition became rapidly worse, and in less than twenty-four hours the whole reservoir was impregnated with this odor. The writer decided immediately to drain the water from the reservoir and pump from the brook direct. By following this course it was possible to leave the bed of the reservoir exposed to air and sunlight, thus enabling oxidation of the decomposing matter to become more complete. Furthermore, the water obtained from the brook was comparatively fresh and free from the odor of the decomposing matter. The chance of contamination incidental to taking water from the flowing stream was eliminated by the liquid chlorine treatment. After the reservoir had been drained for ten days, the offensive matter was sufficiently oxidized so the sluice gates could be closed.

Pumping Equipment.

The Water Company's original equipment consisted of two No. 80 Rife rams and an 8 in. by 12 in. Gould's triplex single-acting pump having a capacity of 300 gal. per minute. This pump

was connected direct to a 10-h.p. gasoline engine. The gasoline engine was subject to internal disorders at unexpected times, and as the storage capacity of the concrete reservoir was less than one day's consumption, it was imperative that additional pumping equipment be installed to reinforce the fire hydrants then being placed throughout the district.

The rams were discarded, and the space utilized for a 10 in. by 12 in. Smith-Vaile triplex power pump, having a rated capacity of 1 050 gal. per minute. This pump is operated through chain drive by a 100 h.p. Westinghouse slip-ring motor. As the unit was to be operated but three to four hours per day, it was thought advisable to provide for automatic operation in case of emergency or extreme low pressure. For this reason there was installed a Westinghouse alternating current magnet switch starter, controlled by a pressure gage switch. This switch is satisfactory for starting the pump on low pressure, but experience has shown that it will not operate within close limits for stopping the pump when the standpipe is filled. A positive action float switch which can be installed at the top of the standpipe will prove the only satisfactory method of automatically controlling the apparatus.

Compression grease cups and ring oiled bearings on pump and motor insure proper lubrication in case the machinery is started with no attendant present. At first the chain drive gave us some trouble in the matter of lubrication, on account of high-speed operation which caused oil to fly off the surface of the chain without working into the links. This difficulty was overcome by installing a perforated one-half inch pipe between the top and the bottom of the chain. An oil cup controlled by a valve feeds oil to the inside of the chain, where centrifugal force works the oil out through the links and keeps the chain properly lubricated.

In order to provide additional storage and higher pressure, a steel standpipe 105 ft. high by 30 ft. diameter was constructed near the old storage tank. This gave an increased capacity of 554 000 gal. and a maximum pressure down town of 87 lb. per sq. in. The working pressure runs from 75 to 80 lb. during the day. There is an available water supply for fire hose without pumping engines of 2 800 gal. per minute in the business district.

Leadite Joints.

In drawing up the proposals for the water mains contract, alternative prices were asked, first on laying cast-iron pipes with lead joints, second on laying cast-iron pipes with leadite joints. The contractor to whom the work was awarded, offered to do the work with leadite joints for 10c. per foot cheaper than with the lead joints. After favorable replies were received from several users of leadite, we determined to use the material.

Leadite was used on about 28 000 ft. of 10-in. water main. The material comes in the form of a black powder put up in 100-lb. bags. We used an ordinary portable furnace, burning coke, controlling the temperature by dampening the fire with soil when necessary. One attendant is kept on this furnace continually, as the material requires constant stirring and proper control of the temperature to prevent burning. The leadite is melted until it is of the consistency of medium oil, and the appearance of the surface of the liquid is smooth and free from bubbles. At this stage it has a mirror-like surface and is ready to pour. The temperature at this time is very slightly above the melting point, and a higher temperature will cause bubbles to appear. Any increase in temperature will cause the material to thicken until it becomes stringy. If this occurs, the pot should be removed from the fire and cooled until the temperature is reduced so that the material is of the proper consistency. Dry jute should be used in the joints. The presence of oil or grease from tarred jute prevents a good bond between the leadite and the cast-iron pipe. The material is poured similar to lead, it being necessary, however, to build the gate at least 3 in. high above the top of the bell. This is required as the material is too light to flow back into the joint at the top of the bell of the pipe without a slight head to force it back. Joints made up with an ordinary gate, such as is used for lead, proved to be imperfect, as the material did not properly fill the joint at the top. The leadite in the gate can be broken from the joint when cold and remelted after being properly cleaned.

Experience proved that we have obtained better results with the joints if the pouring was kept back at least four lengths of pipe from the laying gang. The shock of driving home a new

length of pipe tends to break a freshly made joint. One serious disadvantage in the use of the material is its tendency to crack, being brittle on new work. One 6-in. pipe crossing under a railroad track, which was laid in 1914, has broken down at the joints, and it has been necessary to cut out the leadite and use lead in this location. Another disadvantage in repairing a defective leadite joint is the necessity of shutting the water off the main. It has been found impossible to calk or patch a leadite joint with lead wool or other material. Best results are obtained by entirely removing the leadite from the joint and either repouring the joint with leadite or lead. On the other hand, the ease with which plugs can be cut out or joints cut away in order to remove several lengths of pipe has proven of distinct advantage.

Tests of Leadite Joints.

As the standpipe was not completed when the pipe lines were laid, we were forced to omit exact tests of joints after pouring, but each joint was inspected when a section was filled with water before back filling was done. Final tests were made this year.

The only method available in making these tests was to shut off each service connection at the curb cock and to shut off all gates on adjacent lines. Table 1 gives data showing the number of services and length of service connection involved in the tests, and also the number of gates which it was necessary to close. No doubt some of the water measured as leakage was lost through leaky services or gates, but the results in Table 3 have been figured on the assumption that the total loss of water was through the leadite joints only. The standpipe was pumped full of water, to give the maximum available pressure on the lines to be tested. Table 2 shows the relative pressures on different sections of the line, 35 per cent. of the length ranging from 45 to 70 lb. and 65 per cent. ranging from 70 to 98 lb. per sq. in. The standpipe was shut off from the distribution system and the water supplied for leakage on the tested lines was by-passed through a 1-in. meter. Gage readings of the pressure on the lines were taken at two points during the tests. The duration of the test was four hours; the actual quantity of water registered through the meter was 39.4 cu. ft., or 1 773 gal. per twenty-four hours. Correction for under-

registration of the meter gave a total loss of water from leakage of 1 861 gal. of water per twenty-four hours, or 0.360 gal. per twenty-four hours per linear foot of joint.

Maintenance of System.

The water company, before its purchase by the district, had found it less expensive to have new service connections installed by plumbers than to maintain a gang on this work. Since 1915 the plant has expanded rapidly, and the old methods proved too expensive both in time and money. A maintenance gang was organized, necessary tools and a Ford one-half ton truck were purchased, so that all new work, service connections, and repairs are now handled at a saving of 33 per cent. in cost and in minimum time allowance. The truck can haul a trench pump, tools, and six men for emergency repairs, and get to the job in the shortest possible time.

Waste Prevention.

The water is now sold by flat rate to private consumers, the charges being based on the number of fixtures in use. Business and manufacturing establishments are on meter system. On account of the flat rate system in use there is of course more or less leakage from defective plumbing. This is reduced as far as possible by regular house-to-house inspections, and has resulted in cutting down the consumption from 75.4 gal. per day per person during 1915 and 1916, to 66.5 gal. per day per person during 1916 and 1917.

Municipal ownership of the water-supply system has proven a success in Windsor. The Windsor Fire District is assured of effective fire protection service at cost, and, which is more important, it is assured of a constant supply of water for domestic uses free from disease-carrying bacteria. The department paid the interest on its bond issue during the first year without additional taxation, and during this year has turned over an operating profit of about $2 500.

TABLE 1.

DATA REGARDING MAINS.

Location.	Length of Main. 10 In. Ft.	8 In. Ft.	Total No. Joints. 10 In.	8 In.	6 In.	Services. No.	Length. Ft.	Gates. No.	Size. In.
Sage Park Road....	7 674	128	656	16	7	4	70	3	8
Windsor Avenue....	14 640		1 271		48	58	1 633	2	10
								4	6
Total.............	22 314	128	1 927	16	55	62	1 703		

TABLE 2.

RANGE OF PRESSURE ON MAINS.

Location.	Length. Ft.	Pressure. Lb. per Sq. In.	Per Cent. of Length.
Sage Park Road....	2 228	45	10
Sage Park Road....	5 574	64	25
Windsor Avenue....	7 600	73	34
Windsor Avenue....	4 400	94	19
Windsor Avenue....	2 640	98	12
Total.............	22 442		

TABLE 3.

LEAKAGE — SAGE PARK ROAD AND WINDSOR AVENUE.

Date.	Size Main. In.	Lin. Ft. Joint.	Leakage in Gal. per 24 Hr. Total	Per Lin. Ft. of Joint.
August 24, 1917....	10	10 in. — 5 048		
		8 in. — 33	1 861	0.360
		6 in. — 86		
		5 167		

DISCUSSION.

MR. FRANK L. FULLER. I should like to inquire, Mr. President, how you remove a pipe that has been laid with leadite.

MR. TURNER. Our method of removing a length of pipe is to take an ordinary calking iron and to sharpen it to a point, so that instead of having a flat edge it is drawn out to a long V, and then we cut out the leadite with this tool. The leadite is very brittle and comes out in the form of a powder when the joint is cut. So that we can cut all the material out of the joint, and by cutting out three or four joints we are able to remove a section of the pipe.

MR. FULLER. Did I understand you to say the price was ten cents a foot alone, for laying it with leadite?

MR. TURNER. Yes. I might add that the contractor who did

the work was very faithful in the performance of his duty, otherwise I doubt very much if we would have obtained as good results on our test as we did. I think that the work of putting in leadite joints is something that requires very faithful performance. It is not a work that can be done slipshod.

Mr. Frank E. Merrill. I should like to ask the speaker if he ever tried to burn out leadite joints. This year I have had my first experience with using material of this kind in laying a line of 12-in. pipe, — it was hydrotite which we used, which is similar to leadite, — and we attempted to remove one joint by the use of the chisel, and found it very difficult work to get it out. We built a fire around it and melted it out and got it out very nicely. I should also like to ask if he can give me any idea of the cost of trench work, back-filling, laying, furnishing the joint material and running the joints of a 12-in. pipe with leadite, the pipe to be in a trench five feet deep.

Mr. Turner. In regard to the first question, we have never attempted to burn out the leadite joints, because we found it was very easy to chip it out; in fact, it is a great deal easier to chip out the joint that is made of leadite than it is to burn out a lead joint. In regard to the second question, I am unable to give any figures that would be of value to you as to the cost of laying the 12-in. main. This leadite, I understand, on the last quotation, was quoted at ten cents a pound, which at the present time is somewhat cheaper than lead. It weighs only about one quarter as much as lead, so that it is supposed to go four times as far, although I doubt very much if it does. I think perhaps three times would be a good allowance to make for it.

Mr. P. J. Conlon. Do you think it would be cheaper to dig up four lengths of pipe than to use a sleeve antl cut out one length of pipe, whether leadite or lead?

Mr. Turner. I don't think it would be if we had to dig the main up. It would be very much cheaper to cut out one length of pipe and put in a sleeve than to dig up four lengths. But if you wanted to take out a long line of pipe and salvage the pipe, it is very much easier to cut out the old leadite joints than it is to burn out lead joints. I know that we have had the experience of cutting out plugs on T's which have been inserted in lines for future hydrants, where we find that we can cut out a T in about

ten minutes' time, whereas if we had to burn out a lead joint or cut it out with a chisel it would take very much longer.

Mr. Frank L. Fuller. I should like to inquire, Mr. President, in regard to the tightness of these joints, — whether you had any trouble from leakage.

Mr. Turner. When we first filled our sections of pipe, all of the joints seeped considerably, and some had quite pronounced leaks on them, but after the pressure had been on about twelve hours the leaks all stopped, and after forty-eight hours the seepage all stopped. The joints seem to tighten up after the water is turned on to the line. I notice from our pumping record there was considerable leakage on the new lines for about two weeks after they were laid, and then that was gradually reduced so that at the present time I know that the leakage on the leadite joints is very small, as the result of our tests shows. Where the leakage on twenty thousand odd feet of 10-in. main was at the rate of only $\frac{36}{100}$ of a gallon for twenty-four hours per linear foot of joints, that is, I think, a very good test.

Mr. Fuller. How long has this pipe been laid?

Mr. Turner. This pipe was started in the fall of 1915 and completed in the spring of 1916. The test of the joints was made about three or four weeks ago.

Mr. George A. Stacy. I should like to inquire if you had any trouble with wet joints.

Mr. Turner. We seemed to have a little trouble with wet joints at first. That is, they leaked more than the dry joints did. But the wet joints gradually closed up after the line had been in service for some time. I think that the worst trouble we have had with the leadite joints has been where there was oil or grease which has come in contact with the pipe. For some reason or other, the leadite will not bond on the cast iron if there is grease or oil present. The principal thing in the laying of cast-iron pipe, I think, is to see that the jute is properly driven into the bell. That is the foundation of the joint. And in order to do that you must have the joint big enough to work around it. I don't think we save anything on the bell holes. We excavate our bell holes just exactly as much for leadite as for lead joints.

Mr. Fuller. How deep were the joints?

Mr. Turner. Two and one-half inches deep for leadite.

PROCEEDINGS.

June Outing.

Meeting of the New England Water Works Association was held at Norumbega Park, Newton, Mass., Wednesday, June 13, 1917, at three o'clock P.M., Vice-President Carleton E. Davis presiding.

The following members and guests were present:

Honorary Members.

Frank E. Hall.
George A. Stacy.
Robert J. Thomas. — 3.

Members.

D. L. Agnew.
S. A. Agnew.
L. M. Bancroft.
C. H. Bartlett.
C. A. Bingham.
Alvin Bugbee.
H. B. Burley.
R. D. Chase.
J. E. Conley.
C. E. Davis.
E. D. Eldredge.
R. H. Ellis.
James Fitzgerald.
R. J. Flinn.
H. F. Frost.
F. L. Fuller.
F. C. Gamwell.
F. J. Gifford.
T. C. Gleason.
D. A. Heffernan.
W. F. Howland.
W. F. Hunt.
W. S. Johnson.
Willard Kent.
S. E. Killam.
G. A. King.
C. F. Knowlton.
W. J. Lumbert.
W. E. Maybury.
Hugh McLean.
John Mayo.
H. A. Miller.
W. H. O'Brien.
J. A. Parsons.
E. W. Quinn.
J. H. Remick.
G. A. Sampson.
A. L. Sawyer.
J. E. Sheldon.
C. W. Sherman.
J. W. Smith.
G. T. Staples.
J. T. Stevens.
G. A. Stowers.
J. F. Sullivan.
A. H. Tillson.
R. S. Weston.
G. C. Whipple.
F. H. White.
J. C. Whitney.
G. E. Winslow.
I. S. Wood.
H. D. Woods. — 53.

Associates.

Harold L. Bond Co., G. S. Hedge.
Builders Iron Foundry, A. B. Coulters.
A. M. Byers Co., H. F. Fiske.
Chapman Valve Mfg. Co., J. J. Hartigan.
V. N. Bengle, W. U. Storrs, J. P. Mulgrew, and C. E. Pratt.
Darling Pump & Mfg. Co. (Ltd.), H. A. Snyder.
Garlock Packing Co., L. S. Harris, C. D. Allen.

Goulds Mfg. Co., Creed W. Fulton.
Hersey Mfg. Co., W. A. Hersey, J. H. Smith.
Leadite Co., George McKay, Jr.
Lead Lined Iron Pipe Co., T. E. Dwyer, Wilfred Poor.
Edson Mfg. Co., H. L. B. Watson.
Ludlow Valve Mfg. Co., A. R. Taylor, G. A. Miller.
Mueller Mfg. Co., G. A. Caldwell.
National Meter Co., J. G. Lufkin, H. L. Weston.
Neptune Meter Co., H. H. Kinsey.
Norwood Engineering Co., F. M. Sears.
Pittsburgh Meter Co., J. W. Turner.
Rensselaer Valve Co., C. L. Brown.
A. P. Smith Mfg. Co., F. L. Northrop.
Thomson Meter Co., E. M. Shedd.
Union Water Meter Co., F. E. Hall.
Water Works Equipment Co., W. H. Van Winkle.
R. D. Wood & Co., H. M. Simons.
Worthington Pump & Machinery Corporation, Samuel Harrison, W. T. Bird. — 34.

Guests.

Maine.

Portland, Edward Duddy.

New Hampshire.

Somersworth, C. F. Crockett.

Massachusetts.

Belmont, Mrs. C. W. Sherman.
Boston, Mr. and Mrs. D. A. Ambrose, Mr. and Mrs. J. G. Andrews, Mr. and Mrs. S. E. Thompson, Mr. and Mrs. W. W. Clifford, E. P. Bliss, T. F. Dorsey, A. L. Gammage, C. F. Glavin, Miss Joan M. Ham, Mrs. W. S. Johnson, Mrs. H. H. Kinsey, E. F. Sullivan, J. A. Tomasello.
Braintree, Mrs. W. E. Maybury, L. W. Thayer.
Bridgewater, Mrs. John Mayom, Miss Bulah Hopkins.
Brookline, Mrs. R. S. Weston, Mrs. H. B. Burley.
Canton, C. V. Reynolds.
Dedham, Mrs. F. J. Gifford, Miss S. K. Staples.
Framingham, Mrs. W. T. Howland.
Holyoke, Mrs. F. M. Sears.
Melrose, Mrs. C. F. Knowlton, Charles Knowlton, Jr.
Methuen, Miss Violet Appleyard.
Needham, P. D. G. Hamilton, Mrs. Peter Hamilton.
Newton, Miss Carol Childs, C. D. Bryant, W. P. Morse, Miss Beatrice Slattery.
Northampton, C. P. Houghton.
Norwood, G. A. Smith.
Palmer, Mrs. F. C. Gamwell.
Reading, Mrs. L. M. Bancroft.
Revere, Mr. and Mrs. G. R. Burnes, Mr. and Mrs. H. T. White.
Wellesley, Mrs. W. A. Hersey, Francis Hersey, W. P. Hersey.

Rhode Island.

Narragansett Pier, Mrs. Willard Kent.
Newport, Miss Marion L. Ober, A. J. Ober.

New Jersey.

Trenton, Mrs. Alvin Bugbee. — 55.

On recommendation of the Executive Committee, the following applicants for membership were by unanimous vote made members of the Association:

Walter Elwood MacDonald, city water works engineer, Ottawa, Canada; Herbert T. White, water registrar, Revere, Mass.; and Robert C. Wheeler, civil engineer, Philadelphia, Pa.

A letter from George C. Whipple, president of the Boston Society of Civil Engineers, recommending the adoption by the Association of a resolution favoring Prohibition during the continuance of the present war, together with a letter of endorsement from Caleb Mills Saville, President of this Association, was presented, and it was unanimously voted:

Whereas, on account of a state of war it is necessary that this country conserve its sources of food supply to the utmost; and

Whereas, immense quantities of grain, molasses, and other food products are now used in the manufacture of distilled and fermented liquors,

Be it resolved, that the members of the New England Water Works Association present at this meeting favor such congressional action as will result in the prohibition of the manufacture and sale of distilled and malt liquors in the United States during the continuance of the war; and

Be it resolved, that copies of this resolution be sent to the President of the United States and the Senators and Representatives who represent the New England States in Congress.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

NOVEMBER MEETING.

THE BOSTON CITY CLUB,
BOSTON, MASS., November 14, 1917.

Mr. Caleb M. Saville, President, presiding.

The following members and guests were present:

HONORARY MEMBERS.

E. C. Brooks.	Desmond FitzGerald.	George A. Stacy.
R. C. P. Coggeshall.	Frank E. Hall.	Robert J. Thomas. — 6.

MEMBERS.

L. M. Bancroft.
C. R. Bettes.
J. W. Blackmer.
J. C. Chase
F. L. Cole.
J. E. Conley.
J. H. Cook.
John Cullen.
F. A. Darling.
A. O. Doane.
E. D. Eldredge.
R. H. Ellis.
S. F. Ferguson.
F. L. Fuller.
Patrick Gear.
H. T. Gidley.
F. J. Gifford.
C. R. Hildred.
D. A. Heffernan.
J. L. Howard.
A. C. Howes.
W. T. Howland.
G. A. Johnson.
M. S. Kaharl.
Willard Kent.
S. E. Killam.
G. A. King.
P. J. Lucey.
W. J. Lumbert.
C. E. McDonald.
Hugh McLean.
H. V. Macksey.
A. E. Martin.
John Mayo.
F. E. Merrill
M. L. Miller.
W. H. O'Brien.
T. A. Peirce.
H. E. Perry.
H. G. Pillsbury.
C. R. Preston.
E. W. Quinn.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
G. A. Stowers.
J. F. Sullivan.
H. A. Symonds.
L. D. Thorpe.
E. J. Titcomb.
D. N. Tower.
W. H. Vaughn.
G. E. Winslow.
L. C. Wright. — 55

ASSOCIATES.

Harold L. Bond Co., F. M. Bates, F. W Mattheis.

Builders Iron Foundry, A. B. Coulters.

Central Foundry Co., W. S. Feltt.

Chapman Valve Mfg. Co., H. H. Cook, J. T. Mulgrew, C. E. Pratt.

Hayes Pump & Machinery Co., F. H. Hayes.

Hersey Mfg. Co., J. Herman Smith.

Kennedy Valve Mfg. Co., J. S. Hanlon.

Lead Lined Iron Pipe Co., T. E. Dwyer.

Ludlow Valve Mfg. Co., A. R. Taylor.

National Meter Co., J. G. Lufkin, H. L. Weston.

Neptune Meter Co., H. H. Kinsey.

Pittsburgh Meter Co., J. W. Turner.

Rensselaer Valve Co., C. L. Brown.

A. P. Smith Mfg. Co., F. L. Northrop.

Thomson Meter Co , E. M. Shedd.

Union Water Meter Co., H. W. Jacobs, D. K. Otis, E. K. Otis.

Warren Foundry & Machine Co., W. F. Woodburn.

Water Works Equipment Co., W. H. Van Winkle, Jr.

Worthington Pump & Machinery Corporation, W. F. Bird, Samuel Harrison, E. P. Howard. — 27.

GUESTS.

MASSACHUSETTS.

Boston, George A. Caldwell, G. Ferullo, Eugene F. Leger.

CONNECTICUT.

Hartford, J. F. Shaughnessy, Asst. Engineer, Hartford Water Works. — 4.

THE PRESIDENT. Since our last meeting the Association has met with a great loss in the death of one of its most active and useful members, and it seems fitting that before we begin our regular exercises we should pay some tribute to his memory. I will now call on Mr. Coggeshall to say a few words concerning our late associate, Mr. W. S. Johnson.

MR. R. C. P. COGGESHALL. *Mr. President and Fellow Members,* — Death has been very busy in our ranks of late. We were all shocked by the terrible tragedy that occurred in the early part of the year. Then war came and took from our service our Editor, Colonel Hale, and the Executive Committee selected Mr. Johnson to attend to the work he had left. But hardly had Mr. Johnson got started in the work than he was overtaken by sickness, right in the midst of the preparation of the number of the JOURNAL which you received a few days ago, and he passed away from us. I was not fortunate in knowing Mr. Johnson as intimately as many of you did, but I was engaged with him in committee work during the last two or three years, and I found him very thorough and very painstaking, and I recognized him, as we all did, as a man whose promise for the future was bright. Now he has gone from our midst, and I wish that we might fittingly express our sorrow and our sense of loss. I would suggest, Mr. President, that we all rise and stand for a few moments in silence while our thoughts turn to the memory of our departed friend.

[The members all rose and stood in impressive silence for a few moments.]

THE PRESIDENT. The first business before the Association is in connection with matters which the Secretary has in hand, and I will call upon him to present it.

The Secretary read the following names of applicants for membership, all properly endorsed and recommended by the Executive Committee:

Resident: G. Ferrullo, Boston, Mass., contractor, constructing water works: Herbert M. Tucker, Lebanon, N. H., manager Hartford Water Company water works, White River Junction, Vt.

Non-Resident: A. A. Laflin, St. Stephens, N. B., superintendent water works; Charles Sing Denman, Des Moines, Ia., general

manager Des Moines Water Company; Vratislav Adolph Zehr, civil engineer, Wilkinsburg, Pa.

Associate: Eugene F. Leger, Allston, Mass., installation of pumping and sewage plants (Power Equipment Company).

On motion of Frank L. Fuller, the Secretary was directed to cast one ballot in favor of the applicants, and he having done so they were declared duly elected members of the Association.

Proposed Amendment to the Constitution.

The Secretary. The Executive Committee at its session to-day voted to recommend the following amendment to the Constitution of the New England Water Works Association:

Strike out the whole of Section 2 of Article IV and make it to read as follows:

Sect. 2. The annual dues shall be —		
	For Members,	$5.00
	For Associates,	25.00

That is, in effect, raising the dues of the active members from $3 to $5, and of the associates in the same proportion from $15 to $25. The article in relation to dues now reads:

Article IV.

Dues.

Section 1. The initiation fee shall be —		
	For Resident Members,	$5.00
	For Non-Resident Members,	3.00
	For Associates,	10.00
Sect. 2. The annual dues shall be —		
	For Members,	$3.00
	For Associates,	15.00

In order to amend the Constitution the requirement is:

Article IX.

Amendments.

Section 1. Proposed amendments to this Constitution must be submitted in writing to the Executive Committee, and shall be presented to the Association at a regular meeting, if so decided by a vote of the committee. It shall be the duty of the Executive Committee to bring before the Association any proposed amendment at the written request of ten members.

Sect. 2. Announcements of a proposed amendment which is recommended by the Executive Committee, or by ten members of the Association, shall be given by printing the amendment in the notices of the regular meeting. A two-thirds vote of the members present and voting shall be necessary for the adoption of an amendment.

The President. It is in pursuance of the requirements of the Constitution that this amendment has been read at this time, and proper action will be taken, of course, at the next regular meeting of the Association.

Presentation of the Dexter Brackett Memorial Medal for the Year 1916.

Mr. Desmond FitzGerald. *Mr. President and Fellow Members,* — The next matter on your program is the presentation of the Dexter Brackett medal awarded for the paper which was selected by the committee as the one among those published in the 1916 Proceedings most worthy of it. This is a most interesting occasion for me, and I believe it is for all of you, for two reasons: First, because this act of yours is starting a long historical list of members who will receive this medal in the future; and I believe that it will be an honorable list. In the second place, it is particularly interesting to me because the award has been made to your President who sits immediately at my left, which arrangement makes it very easy for me, because when I hand the medal over to him I shall not even have to take a step to do it.

The first award of the Dexter Brackett medal to Caleb Mills Saville, for his paper entitled, "Some Water Works Experiences in Hartford, Conn.," was announced at the September meeting of this Association. The paper was accompanied by diagrams showing losses of head in 4-in. and 6-in. pipes, which had been in service from thirteen to fifty years, together with tests on centrifugal pumps, fire hydrants, and check valves, besides other interesting data.

Since the award was published the medal has been cast, and it is now in order to make the formal presentation of the medal to Mr. Saville, which, owing to my long association with Mr. Brackett of forty-two years and with Mr. Saville later in the

Metropolitan Water Works, becomes a particularly pleasant duty for me to perform.

The medal was designed by Mr. Theodore Spicer-Simson, of New York, under the supervision of Messrs. Stearns, Hazen, Flinn, and Stacy, of this Association. This is a bronze medal, about 3 in. in diameter, so that Mr. Saville, or any of his successors in the award, need not hesitate to keep it in his desk or at his home. Had the medal been made of gold, this could not be done without danger of losing the medal by theft, a contingency which accompanies the Norman gold medals of the American Society of Civil Engineers, and which makes it necessary that they shall be kept in some safety deposit vault.

On the obverse of this Brackett medal is an excellent likeness of Mr. Brackett, whose kindly face was familiar to you all, with his name and the period covered by his life, 1851 to 1915. I think no one can fail to recognize this as a very excellent likeness of Mr. Brackett. On the reverse of the medal is a very appropriate device, a fountain in the shape of a pyramid, with three basins, one above the other; and surrounding it, on the outside, is the name of this Association in large letters, — "New England Water Works Association." And in connection with that inscription is the name of Mr. Saville, to whom the medal is presented. Close to the fountain are the words "For the most meritorious paper, 1916."

Now, in behalf of the committee appointed to make the award of this medal, I take great pleasure in handing it over to our excellent President, Mr. Saville, and I know that it will be treasured by him all through his life. [*Applause.*]

President Saville. *Mr. Chairman and Gentlemen of the Association,* — It is with peculiar gratification that I receive this medal which it has been your pleasure to hand to me. Several emotions stir me as I receive it, the least of which is due to the fact that my paper was chosen among many excellent papers. The greatest pleasure that comes to me is from the fact of my own long personal association with Mr. Brackett. Mr. Brackett was more than a chief to me; he was a personal friend. For about twenty years I was associated with him, going to the Metropolitan Water Works at a time very shortly after he went there, going

with two others at about the same time, members of this Association, and we three — Mr. John L. Howard and Mr. W. E. Foss and myself — being at that time Mr. Brackett's chief assistants. Mr. FitzGerald also was there, and that fact makes it particularly pleasant for me to receive this medal from his hands.

Mr. Brackett you all knew, and it is not for me to say anything about his work, but I would think of him as I knew him in the later part of his life, as a very, very dear friend. You know how his face would light up when you went in to see him, and it is with that appreciation of him that I am glad to have this medal. I thank you for it, gentlemen, and I thank you very sincerely. [*Applause.*]

There is one other matter of business at this time, and that is the report of Mr. William F. Woodburn upon matters under his charge at the last annual convention.

REPORT OF EXHIBIT COMMITTEE — HARTFORD CONVENTION, 1917.

BOSTON, MASS., October 3, 1917.

Mr. CALEB MILLS SAVILLE, *President*,
NEW ENGLAND WATER WORKS ASSOCIATION,
HARTFORD, CONN.

Dear Sir, — I am pleased to submit the following report of the Exhibit Committee's work at Hartford.

Owing to the war and other unusual conditions prevailing this year, our exhibit was not as large as at some other conventions, but I feel safe in saying that the interest displayed by the delegates was greater than at any exhibit I have ever attended, and many of the exhibitors advised me that it was the most successful exhibit from a business standpoint that they had ever attended.

The following of our associate members made exhibits, a total of 40:

American Bitumastic Enamels Co.
The American City.
Builders Iron Foundry.
Central Brass Mfg. Co.
Central Foundry Co.
Chapman Valve Mfg. Co.
Chicago Pneumatic Tool Co.
Joseph Dixon Crucible Co.
Eddy Valve Co.
Electro Bleaching Gas Co.
Engineering News-Record.
Fire and Water Engineering.

Goulds Mfg. Co.
Hersey Mfg. Co.
Kennedy Valve Co.
The Leadite Co.
Lead Lined Iron Pipe Co.
Lock Joint Pipe Co.
Alexander Milburn Co.
Municipal Journal.
National Meter Co.
National Water Main Cleaning Co.
Neptune Meter Co.
Norwood Engineering Co.
The Pitometer Co.
Pittsburgh Meter Co.
Pratt & Cady Co., Inc.
H. Mueller Mfg. Co.
Chris D. Schramm & Son.
A. P. Smith Mfg. Co.
Thomson Meter Co.
Union Water Meter Co.
United Brass Mfg. Co.
Wallace & Tiernan Co., Inc.
Warren Foundry and Machine Co.
Water Works Equipment Co.
R. D. Wood & Co.
Worthington Pump and Machinery Co.
S. E. T. Valve and Hydrant Co.
United States Cast Iron Pipe and Foundry Co.

(Signed) WM. F. WOODBURN,
Chairman Exhibit Committee.

On motion, duly seconded, the report was accepted and the committee was given a rising vote of thanks.

The President then called on Mr. J. H. Shaughnessy, assistant engineer, Hartford Water-Works System, who presented a paper on the "Construction of Earth Dam on Phelps Brook, Hartford's Water-Works System." After the reading of the paper, President Saville gave some further information in regard to the work.

Mr. Henry A. Symonds read an experience paper, contributed by Mr. A. N. French, superintendent of water works, Seneca Falls, N. Y., on "A Small Water-Works Testing Laboratory." The paper was accompanied by the following letter:

Seneca Falls, N. Y.,
October 30, 1917.

Willard Kent, *Secretary*,
N. E. W. W. Association:

Dear Sir, — I am enclosing a little tale of experience which you are at liberty to present at some winter meeting of the Association, if you think it worth while. I will leave it to your judgment. If you do not think it will be of enough interest to have it read, I shall find no fault.

I am sorry that I cannot attend any meetings, these days, but the distance is too great.

Very truly yours,
(Signed) A. N. French.

Mr. French's paper was discussed by Mr. Robert Spurr Weston and President Saville, who in closing his remarks said:

"I think, as long as we are on this matter, the Association would be interested in hearing some of Mr. FitzGerald's experiences. Mr. FitzGerald is really the father, in a way, of water-works laboratory investigations. I think the laboratory at the Chestnut Hill Reservoir was where first were begun some of the investigations that have become classic, and some of the men that started in their work there have since made national reputations for themselves. If Mr. FitzGerald will tell us a few of his experiences, I think it will be very interesting." (*Applause.*)

Mr. Desmond FitzGerald. It is an interesting thing for an old war horse like myself to know that the young fellows are having very much the same kind of troubles to-day that we had way back in 1873, which was the first year that I went to the Boston Water Works. It fell to my lot really, as your President has said, to start the first laboratory in this country — or in any country, I believe — especially for water-works investigations. But we had lots of troubles, back there in 1873, and along up through the eighties, with the Boston water, and the funny part of it was that the experts in those days couldn't tell us anything about what the causes of those troubles were. We would frequently have the water in such bad condition that you couldn't even clean your teeth with it with any degree of pleasure. It was due to the growth of asterionella, as we found out after awhile, but at that time there wasn't any expert chemist or physicist we could find — and we even went down to Johns Hopkins — who

could really tell us what the trouble was or what to do to remedy it. We were having at that time, I think, an income of about \$2 000 000 from our works, and I thought that if the Boston Water Board would give me about \$10 000 a year I could try to see if I couldn't find out for myself. The Board very kindly gave me that money.

Now I haven't time, in the five or ten minutes your President has given me, to tell you all about the troubles we had, — what we had to do and what we found out, and how interesting it all was, — but I will tell you one little incident that happened at one time, which came into my mind a moment ago. I wonder if anybody else here has ever had the same sort of experience. We were very short of water — and what town or city has not been in that condition? But I was very young and it worried me a great deal, this idea of supplying a city of two or three hundred thousand population from a lake which was only good for about 12 or 13 million gallons a day, and they were using 16 or 17 millions, and rapidly mounting to 20. Well, I told one of the old officials on our works that I couldn't sleep at night, thinking of the dangers that this great city with all its wealth was undergoing, for I knew that at any time a drought might come which would knock out the supply. "Well," said he, "after you have been on the works thirty or forty years, as I have been, you will go to sleep soundly at night and not worry." [*Laughter.*]

We were running the old Cochituate aqueduct, at that time, under just sufficient head to get the water down to the Chestnut Hill Reservoir. We had a drought, and one day the water began to go down below the top of the aqueduct, and that was a time when I thought I was justified in losing some sleep. After a while it got down to the middle of the aqueduct, and it was going so rapidly that I built a platform out in the middle of the lake and set up some centrifugal pumps and pumped the water into the aqueduct to keep it full. Finally the water in the lake got below the bottom of the aqueduct, and at the same time the papers in Boston were charging the engineer in charge of the works with drawing off the water at the outlet of Lake Cochituate for the sake of getting a \$5 000 000 appropriation for the Sudbury River works. That was a most disturbing thing. [*Laughter.*]

Now I am going to tell you of something which happened one night. It took both of those pumps to keep the water running at the rate of 20 000 000 gal. per day through the aqueduct, pumping from the deeper portion of the lake up over the stop-planks into the aqueduct. One night, as I was going to bed, I got a telegram saying one of the pumps had gone out of commission, but that the aqueduct was still full of water. In other words, one pump with a capacity of 18 000 000 gal. a day was filling that aqueduct which was carrying 20 or 22 million. Well, I got up and harnessed my own horse, as we did in those days, and drove up there in the middle of the night, and there was the aqueduct full, the water coming down as usual, and one pump only keeping it full. In other words, that one pump was pumping about 16 million gallons a day, and 22 millions were going down the aqueduct. Well, I was about at my wits' end, but I was bound to find out. It was in the middle of the winter, one of the most severe winters we had ever had. I ordered the pump stopped, and the water fell, and then I put a small boat in, with one of my best men in it, and another man with him, and sent him down to find out what the trouble was; and after they had gone down some ways they heard a roar like Niagara; and they went on a little further and they found a stream of water coming down into the aqueduct, about $2\frac{1}{2}$ ft. in diameter, a solid sheet of water, from the outside coming directly into the aqueduct and filling it quité full. Well, that was a poser. So I sent them in again to get the exact position of the station, and they came back with it; and then I sent other men down to find out where the water was coming from on the outside, and they all came back and reported that they couldn't see a thing; that there wasn't any water flowing down. Well, what would you have done under those conditions? Of course I went down myself, and I found the exact point, and I found it was in a heavy cut, and that the ice in this cut was very thick indeed. I immediately sent for choppers, and we cut a hole and we found the ice was two or three feet thick. Then the whole thing became apparent to me. There was a brook going down through this cut, and the brook had a larger amount of water than usual flowing in it, but the ice had frozen over the top of it and the ice had risen and given the brook a chance to flow under-

neath, which was very accommodating. And when we got down through that ice, two or three feet thick, — it had been freezing in layers, as more water came on top it froze, — and finally it got such a grip on the manhole of the aqueduct that it lifted the manhole and part of the brickwork off with it, and allowed the water of the brook to flow down. [*Laughter.*]

Now, gentlemen, I think you will agree with me that that is the easiest way of getting a water supply you ever heard of. But how about the quality? Well, I didn't stop to find out about the quality. But the difficulty of getting that place fixed up and the water stopped you may imagine, in the dead of a severe winter. But that is one of the interesting little incidents that occurred to me, and I am very sorry that I cannot stay longer with you and tell you some more stories. If you will invite me up here some time to a good dinner like this, however, I will agree to tell you some more. [*Applause and laughter.*]

The President. The Secretary says that you have a standing invitation. [*Applause.*]

Mr. FitzGerald. Thank you, I had rather have a sitting one. [*Laughter.*]

The President. We have about fifteen minutes more before we must give up this room. We haven't heard anything from our friend from Holyoke for a long while, and if Mr. Gear will tell us about some of his experiences up there I know we shall all go away feeling very happy. [*Laughter.*]

Mr. Patrick Gear. Mr. President, I don't know what kind of a story I can tell you; but, referring to the first subject we had here to-day, presented by Mr. Coggeshall, I never knew Mr. Johnson died until this morning. I got acquainted with him a year ago; he was in Holyoke two or three times, and this Society has lost a good friend. He was a conscientious worker for anything he was ever asked to do, and I was sorry when I met him in Hartford and saw he wasn't very well, and I was more sorry when I heard to-day he had passed away. I have heard Mr. Johnson read papers at this convention, and no matter what kind of a subject he took up he always went into it very thoroughly. If he had had a paper last year I think he would have been a strong competitor with our President for the Brackett memorial, because he always went very thoroughly into any subject he took up.

We haven't been doing very much work up in Holyoke this year, but I happened to think, when the gentleman was speaking a little while ago, that we built a dam in Holyoke, and I think I will ask our engineer to tell you about it at some time. He had some difficulty in carrying his machine along and dumping his concrete into his forms. I went up there one day and they were getting it up a steep platform. Help was scarce, — it was hard to keep them out in the woods, twenty miles from anywhere. And I was pleased when I saw the engineer had arranged a tandem to run the wheelbarrows up the platform. I don't know as I ever saw a tandem of that kind before, one man ahead pulling and another man behind pushing; but it was a successful tandem, and it was the only way he could hold the men to the work, to have this tandem team running up a wheelbarrowful of concrete. The job is finished now, and if anybody from the Association will come to Holyoke I will guarantee to take him out there and show him a nice little job of concrete and give him a good dinner, and it won't cost him a nickel. [*Applause and laughter.*]

Adjourned.

December Meeting.

Hotel Brunswick,
Boston, Mass., December 12, 1917.

The President, Mr. Caleb M. Saville, in the chair.

The following members and guests were present:

Honorary Members.

Edwin C. Brooks.	Desmond FitzGerald.	Robert J. Thomas. — 5.
R. C. P. Coggeshall.	Frank E. Hall.	

Members.

L. M. Bancroft.	A. E. Blackmer.	F. L. Cole.
F. A. Barbour.	J. W. Blackmer.	H. S. Crocker.
J. F. Barrett.	H. R. Buck.	John Cullen.
G. W. Batchelder.	J. C. Chase.	F. A. Darling.
F. W. Bateman.	H. W. Clark.	C. E. Davis.

J. M. Diven.
A. O. Doane.
E. D. Eldredge.
G. Ferullo.
F. L. Fuller.
G. W. Fuller.
Patrick Gear.
F. J. Gifford.
P. T. Gray.
T. G. Hazard, Jr.
D. A. Heffernan.
J. L. Howard.
A. C. Howes.
J. A. Hoy.
W. F. Hunt.
J. L. Hyde.
Willard Kent.
S. E. Killam.
G. A. King.
P. J. Lucey.
C. E. MacDonald.
F. A. McInnes.
H. V. Macksey.
W. E. Maybury.
John Mayo.
J. H. Mendell.
Leonard Metcalf.
C. E. Peirce.
T. A. Peirce.
H. G. Pillsbury.
C. R. Preston.
C. L. Rice.
G. A. Sampson.
H. W. Sanderson
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
C. W. Sherman.
G. H. Snell.
H. A. Symonds.
Milton Thorne.
E. J. Titcomb.
D. N. Tower.
W. H. Baughn.
I. S. Wood.
M. B. Wright. — 61.

Associates.

Harold L. Bond Co., F. M. Bates, H. H. Sinclair.
Builders Iron Foundry, A. B. Coulters.
Byers, A. M. Co., H. F. Fiske.
Central Foundry Co., R. W. Conrow.
Chapman Valve Mfg. Co., C. E. Pratt.
Chicago Pneumatic Tool Co., F. S. Eggleston, Jr.
Donaldson Iron Co., C. F. Glavin.
Eddy Valve Co., H. R. Prescott.
Garlock Packing Co., C. D. Allen.
Hammond Process Co., P. J. Pickett, J. L. Flinn.
Hayes Pump & Machinery Co., F. H. Hayes.
Hersey Mfg. Co., J. H. Smith, W. A. Hersey.
Ludlow Valve Mfg. Co., G. A. Miller.
National Meter Co., J. G. Lufkin, H. L. Weston.
Neptune Meter Co., H. H. Kinsey.
Pittsburgh Meter Co., J. W. Turner.
Rensselaer Valve Co., C. L. Brown.
A. P. Smith Mfg. Co., F. L. Northrop.
Thomson Meter Co., E. M. Shedd.
Union Water Meter Co., D. K. Otis, H. W. Jacobs.
Warren Foundry & Machine Co., W. F. Woodburn, J. H. Morrison.
Water Works Equipment Co., W. H. Van Winkle.
R. D. Wood Co., Charles R. Wood.
Worthington Pump and Machinery Corporation, Samuel Harrison. — 30.

Guests.

Massachusetts.

Boston, George A. Caldwell.
Fall River, H. C. Bryant.
Brockton, Frank H. Kennedy.

Rhode Island.

Providence, J. D. Savage.
East Greenwich, James Kinlock. — 5.

The Secretary presented the following applications for membership, properly endorsed and recommended by the Executive Committee:

Non-Resident: Frederic E. Beck, Utica, N. Y., engineer consolidated Water Co., Utica; John Y. Lavery, Summit, N. J., city engineer.

Associate: Donaldson Iron Co., Emaus, Pa.; Hammond Process Co., Boston, Mass., paint manufacturers.

On motion of Mr. Coggeshall, the Secretary was empowered to cast one vote in favor of the admission of the applicants named, and, he having done so, they were declared elected members of the Association.

The President called upon Mr. McInnes to present the report of the Committee on Cast-Iron Pipe Specifications. Mr. McInnes stated that owing to circumstances over which the committee had had no control they were not ready to make a report at the present time, but hoped to be able to report at the next meeting of the Association.

THE PRESIDENT. The next business is action on the proposed amendment to the Constitution by striking out the whole of Section 2, Article IV, so that it will read as follows:

Sect. 2. The annual dues shall be —

For Members,	$5.00
For Associates,	25.00

I will say that the Executive Committee referred this matter to the Committee on Finance, of which Mr. Leonard Metcalf is chairman, and I will ask him to make a statement in regard thereto.

MR. LEONARD METCALF. *Mr. President and Gentlemen,* — I think perhaps the briefest way of presenting this to you will be to read the report which was made to the Executive Committee:

BOSTON, MASS., December 1, 1917.

TO THE EXECUTIVE COMMITTEE OF THE
NEW ENGLAND WATER WORKS ASSOCIATION,
TREMONT TEMPLE, BOSTON, MASS.

Your Committee on Finance, of the Association, have given careful study to the revenue and expenditures of the Association during the past, — in particular the past seven years; to its present condition, and the probable

figures for the uncompleted year 1917; and have made an estimate of the revenue and expenditures for the year 1918. The figures developed are appended hereto.

An examination of these figures, and the more distant financial history of the Association, indicates that for a number of years the revenue and expenditures were approximately balanced, — an excess of revenue in one year being counterbalanced by an excess of expense following. Since the year 1912, however, the excess of revenue over expense has been dwindling, and the available resources of the Association have suffered material loss, without hope of recovery if the past activities of the Association are to be maintained.

The excess of revenue in the years 1911 and 1912 but little more than offset the deficit of the year 1910. In the year 1913 a small deficit was incurred, which was not quite offset by the surplus of 1914. In the year 1915 a very substantial excess of expenditures over revenue was incurred, including some figures carried forward from the previous fiscal year on account of the JOURNAL; in the year 1916 revenue and expenditures balanced, and for the current year the revenue will again be materially less than the anticipated expenditures, as will be the case in the year 1918 upon the present revenue basis.

The estimate for the year 1918 indicates that the revenue, predicated on the present annual dues and necessary expenditures, will fall below the expenditures by from $800 to $1 200. This estimate is based on the assumption that strict economy will be exercised, and that all proposed expenditures will be carefully scrutinized and unnecessary items eliminated. To reach even these figures greater economy will have to be observed than has been common to the Association during recent years. It is possible, perhaps probable, that costs will increase as the years go by, and make deficits, with the present revenue scale, even greater in succeeding years.

If the Association is to make both ends meet, it will therefore be necessary either to curtail the present activities of the Association as well as to maintain strictest economy, or to find new sources of revenue through increase in advertising income or charges to members.

While strict economy should, of course, be observed, it does not seem desirable to your committee to attempt to curtail the field of activity of the Association. It does not seem practicable to increase the revenue by increase in advertising rates, and experience does not indicate that a large increase in amount of advertising can be hoped for. It appears to your committee, therefore, that it is the part of wisdom to increase the annual dues, and, in view of the method adopted for meeting the substantial expenses of the annual convention, it appears desirable that the increase in dues should be limited to the members rather than to the members and associates.

For the year 1918 it is probable that the revenue and expenditures can be approximately balanced if the dues of active members are increased from $3 to $4 per year, — the dues of associates remaining unchanged. It is possible that in view of the condition of the times it may prove desirable to ask for a voluntary subscription of $1 each, in excess of the suggested $4 annual dues,

from such members as may feel in a position to make such contribution, and your committee is not at all confident that this increase will be sufficient for future years; but the committee deems it wiser to make the transition from the present dues to whatever figure may prove necessary for the future, by steps, rather than to make the more radical increase in dues from $3 to $5 for members or to add to the dues of associates at the present time.

The committee therefore recommends that the Constitution be amended by changing the amount of the annual dues of members from $3 to $4, and that the Executive Committee be authorized to ask for voluntary contributions from members of the sum of $1, should it appear more desirable to call for such subscription than to attempt to market the securities owned by the Association at the present time.

Respectfully submitted,

LEONARD METCALF.
CHARLES W. SHERMAN.
H. V. MACKSEY.
LEWIS M. BANCROFT.
R. C. P. COGGESHALL.
CARLETON E. DAVIS.
WILLARD KENT.
C. M. SAVILLE.
S. E. KILLAM.

Mr. Metcalf, in explanation of the report, stated that the committee favored making dues for active members $4, but feared dues of $5 might affect membership under present conditions. No increase was advised in dues of associate members, owing to large contributions from them at the conventions.

It was suggested that economy might be effected by eliminating music at dinners and leaving it to the members who smoke to furnish their own cigars, the amount of such annual saving being $50 to $60 for cigars and $100 to $120 for music. Further economy was practicable through cutting out unessential material from the JOURNAL, some organizations having considered suspending publications of their journals during the period of the war. A possible economy might be omitting the luncheons as a feature of the meetings.

Mr. Metcalf expressed his personal opinion in favor of continuing the activities of the Association virtually as in the past, and that it was particularly important at present for water-works men to get together to discuss the new problems which arise, due

NEW ENGLAND WATER WORKS ASSOCIATION — COMMITTEE ON FINANCE.

November 26, 1917. ANNUAL REVENUE AND EXPENSE. Leonard Metcalf.

Condensed Statement.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917 to Oct. 31.	Estimated Forecast. 1917 Total.	Estimated Forecast. For 1918.
Revenue:										
1. Members	$3 145	$3 094	$3 064	$3 197	$3 732	$4 008	$4 546		$4 195	$4 000
2. JOURNAL	2 160	2 267	2 468	1 810	2 546	2 152	2 287		2 140	2 125
3. Miscel., dinners, certificates, etc.	1 014	889	1 116	895	1 187	958	1 048		915	825
Sub-total	$6 319	$6 250	$6 648	$5 902	$7 465	$7 118	$7 881		$7 250	$6 950
4. Dividends & interest	188	191	214	221	221	221	141		125	125
Sub-total	$6 507	$6 441	$6 862	$6 123	$7 686	$7 339	$8 022		$7 375	$ 7075
5. Mfrs. Assoc. for Conv.*	.....	.....	.....	.....	.....	.....	1 000		.....	.....
Total revenue	$6 507	$6 441	$6 862	$6 123	$7 686	$7 339	$9 022		$7 375	$7 075
Expenditures:										
1. JOURNAL	$3 603	$3 209	$2 358	$3 092	$3 401	$4 841	$3 340		$3 740	$3 785
2. Office	1 960	1 683	2 048	1 912	1 885	2 150	2 274		2 645	2 745
3. Meeting & committees	1 675	1 388	1 529	1 530	2 151	1 578	2 403		2 315	1 340
Sub-total	$7 238	$6 280	$5 935	$6 534	$7 437	$8 569	$8 017		$8 700	$7 870
4. Convention expenses*.	.....	.....	.....	.....	.....	.....	1 000		.....	.....
Total expenditures	$7 238	$6 280	$5 935	$6 534	$7 437	$8 569	$9 017		$8 700	$7 870
Net revenue for year	−$731	$161	$927	−$411	$249	−$1,230	$5		−$1,325	−$795
Balance brought forward, January 1	3 450	2 719	2 880	3 807	3 396	3 645	2 415		2 420	1 095
Balance carried forward, December 31	$2 719	$2 880	$3 807	$3 396	$3 645	$2 415	$2 420		$1 095	$300

* Prior to 1916, the convention expenses were paid by contributions disbursed directly through the convention committee of the Association, and not through the Treasurer.

New England Water Works Association — Committee on Finance.

November 26, 1917. Annual Revenue and Expense. Leonard Metcalf.

Year ending December 31.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917 to Oct. 31.	Estimated Total, 1917.	Estimate for 1918.
Honorary Members	13	12	12	12	11	18	17			
Members	678	680	666	686	766	862	942			
Associates	56	58	53	60	70	81	84			
Total membership	747	750	731	758	847	961	1 043			
Journal — Volume	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX			
Cost (4 issues)	$3 491	$2 626	$2 477	$3 586	$3 346	$4 243	$3 387			
Cost per page*	4.32	4.02	4.37	4.89	4.65	5.47	4.79			
Cost per member	4.78	3.50	3.35	4.81	4.17	4.68	3.38			
Number of pages, total	808	654	567	733	719	776	707			
Number of pages of text	643	475	401	554	564	596	538			
Copies printed	1 000	1 000	1 000	1 000	1 050	1 325	1 500			
Circulation at end of year	840	840	826	858	951	1 079	1 155			
Revenue:										
1. Members. Initiation fees	$275	$223	$197	$281	$619	$274	$682		$175	$150
Dues from members	2 870	2 871	2 867	2 916	2 217	2 623	2 670		2 720	2 650
Dues from associated					896	1 111	1 194		1 300	1 200
2. Journal. Advertisements	1 736	1 764	1 839	1 371	1 988	1 755	1 765		1 611	1 800
Subscriptions	168	183	213	258	243	213	231		110	150
Sales	196	279	266	149	215	142	265		399	150
Reprints	60	41	150	32	100	42	26		20	25
3. Miscellaneous. Receipts Pipe Specifications	44	62	41	31	43	20	33			
Dinners	950	821	670	670	1 035	837	708		850	800
Excursions	...	...	405	194	...	...	...		...	...
Certificates, buttons, miscellaneous	20	6	...	...	109	101	307		65	25
Sub-total	$6,319	$6 250	$6 648	$5 902	$7 465	$7 118	$7 881		$7 250	$6 950
4. Dividends and interest	188	191	214	221	221	221	141		125	125
Total revenue	$6 507	$6 441	$6 862	$6 123	$7 686	$7 339	$8 022		$7 375	$7 075
Manufacturers Association for Convention	...	...	...	...	...	...	†1 000		...	...
							$9 022			

Expenditures:										
1. JOURNAL. Advertising Agent	$237	$272	$250	$242	$239	$226	$239		$230	$200
Plates	74	146	71	318	142	188	98		70	75
Printing	2 541	2 117	1 215	1 638	2 019	3 452	2 067		2 600	2 500
Editor's salary	307	300	300	300	300	375	225		300	300
Editor's expense	23	52	31	37	43	48	35		30	35
Advance reports	...	...	...	169	90	19	131		30	100
Reporting	343	58	265	141	280	297	242		220	250
Reprints	25	222	197	190	253	161	225		160	200
Envelopes, postage, miscellaneous	52	42	29	57	35	75	78		100	125
2. Office, Secretary's salary	200	150	250	200	200	200	200		200	200
Secretary's expense	87	46	63	32	50	26	27		40	40
Assistant to Secretary's salary	600	600	600	600	600	600	800		890	1 080
Assistant to Secretary's expense	155	139	159	165	194	293	372		300	200
Rent	533	300	500	300	400	400	404		650	650
Printing, stationery, postage, miscel.	208	262	285	416	239	418	280		300	300
Membership lists	176	186	191	199	202	213	191		265	275
3. Meetings and Committees. Stereopticon	22	69	51	72	40	50	40		45	70
Dinners and incidentals	924	975	810	817	1 188	1 041	916		900	900
Printing, stationery, postage, library	304	208	161	178	637	299	894		190	300
Badges and tracing	52	56	47	78	...	21	117		...	...
Treasurer's salary and bond	68	68	68	68	68	68	68		70	70
Certificates of membership	...	...	...	...	125	51	26		...	...
Miscellaneous excursions	217	...	373	317	25	...	62		...	...
Miscellaneous committees	88	...	...	...	...	...	...		...	...
Miscellaneous expenses	...	12	19	...	68	48	21		...	...
Printing indexes	...	...	...	...	...	...	151		580	...
Reporting (exclusive of JOURNAL)	...	...	...	...	...	...	108		50	...
Furniture	...	...	...	...	...	...	...		480	...
Total expenditures	$7 238	$6 280	$5 935	$6 534	$7 437	$8 569	$8 017		$8 700	$7 870
Convention expenses	...	...	...	...	...	...	†1 000	...	...	...
							$9 017			
Net revenue	—$731	$161	$927	—$411	$249	—$1 230	$5		—$1 325	—$795
Balance brought forward January 1	$3 450	$2 719	$2,880	$3,807	$3 396	$3 645	$2 415		$2 420	$1 095
Balance carried forward December 31	$2 719	$2 880	$3 807	$3 396	$3 645	$2 415	$2 420		$1 095	$300

* See page 153, Vol. XXVII, 1913.

† Prior to 1916, the convention expenses were paid by contributions disbursed directly through the convention committee of the Association, and not through the Treasurer.

to present conditions. Probably little could be saved to the members by curtailing or doing away with the luncheons. It seemed advisable to continue the publication of the JOURNAL, but to do everything possible to condense information, and suggested that authors should be content with the thought that such a course is serving the best interest of the membership at large.

It is important not to increase dues more than absolutely necessary, for we want it to be just as easy and just as desirable as possible for all men, particularly the younger men, to join the Association and become active members.

On motion of Mr. Coggeshall, it was voted to receive the report.

Mr. Coggeshall then moved that the report be accepted.

Mr. Desmond FitzGerald suggested that the first step in retrenchment be the giving up of music at the dinners.

MR. CHARLES R. WOOD. It seems to me that the associate members might be able to stand an increase in their dues, and if you increase the dues of the active members to $4, I think the associate members should pay $20. I think $25 is too high. Speaking for my own company, I think we would be glad to pay $20 to help out the finances of the Association.

MR. CONROW. Speaking for my company, I agree with Mr. Wood, and I think we would be very glad to pay either $20 or $25, whichever the Association think they need.

Mr. J. M. Diven favored an increase of dues of active members to $5, rather than cutting down the JOURNAL, as the sole benefit of the Association to many members is the JOURNAL. Mr. Diven also spoke of the efforts of the associate members for the benefit of the Association, especially in time and money in entertainment and exhibits at the conventions, and suggested $15 for associate members' dues instead of $25.

Mr. METCALF. May I say a word in explanation of the effect of raising the dues. I did not read you a statement of the revenue and expense, which I assume will be published in the JOURNAL. We have at the present time something over 1 000 members. An increase of $1 in the dues would give us $1 000. The increased cost will vary between $800 and $1 200. Now, we have 84 associate members, so that an increase of $5 in the dues of the associate members would mean about $400. We felt that that might be

burdensome to some of the associates, so that we might lose them, and therefore the increase in the amount of associates' dues might not mean a very substantial increase in revenue to the Association. To meet Mr. Diven's point in regard to the JOURNAL, I think he misunderstood what I said. It is not the suggestion of the committee that the JOURNAL should not be published, or should be decreased in bulk arbitrarily, but merely that we should boil down the information which was contained in the papers and get rid of the redundant material.

MR. DIVEN. The dues of the American Water Works Association were increased from $3 to $5. At the time the membership was between 500 and 600, and the loss of membership by the increase was 11. I do not believe the increase here will make a difference of a dozen members.

Mr. Coggeshall's motion that the report of the committee be accepted was put and adopted.

MR. FITZGERALD. Now, Mr. President, in the line of economy, I move that during our dinners the music be dispensed with, at any rate, for the period of the war.

The motion was adopted by a rising vote of 39 to 22.

MR. MACKSEY. I now move that the members individually be accorded the privilege of purchasing their own cigars.

The motion was adopted.

THE PRESIDENT. The question will now be brought before the house whether this proposed amendment to the Constitution shall be acted on favorably or not. The proposed amendment is that the annual dues shall be for members $5, and for associates $25.

MR. DIVEN. I move to substitute $15 for $25, as the dues for associate members, leaving their dues as they are, and increasing the dues of the active members. Of course, the associate members will put it on our bills when they sell us anything. [*Laughter.*] I don't like to be so dependent on the associate members. I believe the active members should support the Association. The associates contribute a good deal, and if they want to contribute a little more, they can take an advertisement in the JOURNAL. I don't think any of them take such an advertisement now for the benefit they get from it, but it is more to help out the JOURNAL.

Mr. Macksey. Mr. Chairman, I move you that the motion to amend the Constitution be amended, so that it shall read that the active members shall pay $4 and the associate members shall pay $20 per year.

The President. Mr. Diven's motion was not seconded. The motion made by Mr. Macksey has been seconded, and it is now open for discussion.

Mr. Macksey. The reason I make this motion is because there seems to be a diversity of opinion, some agreeing with the committee that the dues of active members should be increased $1, and that no increase should be made in the dues of the associate members; and some of the associate members, as you have already noticed, being in favor of bearing a fair share of the increased cost of running the Association, while the last speaker believes that the associate members are now paying enough. Gentlemen, this isn't a question of paying enough. I look at it this way: That the associate members of this Association are members of the Association. They have the interests of this Association as much at heart as the active members have, and if the cost of running this Association has increased so that somebody has got to bear the burden, I do not think the associate members intend to stand back and say, "Let the active members pay the bills, we are not going to pay any more." I do not expect to see them take that attitude at all. There is a certain additional amount of money to be raised if this Association is to live and pay its bills during the time that prices remain as they are.

I think you will bear me out when I say that the salaries of the active members of this Association have been increased but very little to meet the increased cost of living; whereas the cost of the goods manufactured by our associate members has been increased many, many times, and it makes very little difference whether the active members or their employers object to this increase or not, they must pay the bills if they want to get the goods. We all know the principle on which business is conducted is this: that all costs are charged to the goods, and if there is a dollar or two or five or ten dollars a year added on to the expense of selling the goods of a small concern, like the Mueller's, let us say, or the Ludlow Valve Company, or some concern of that kind,

it will disappear into the selling cost and will be figured when they figure how they will sell the goods.

It isn't fair to say that because the associate members, under the name of the Manufacturers' Association, I believe it is, contribute towards the running of the conventions, they should be allowed in here at a low rate. I don't believe in that at all. I believe they should pay their fair share of the running cost of this Association in their dues, where it will show. The officers of this Association and the officers of the Manufacturers' Association know about this contribution for the convention, but the average run of the members know very little about it, but they do know what is paid as dues. Now, I think that if, under the circumstances, the active membership will stand for a certain percentage of increase, the associate membership can stand for a similar percentage of increase. I have heard some talk that the representatives of some of the associate members say that if we charge any more they will get out. Well, gentlemen, if they think so little of their membership in this Association that $5 a year can drive them out, if they have so little sympathy with the aims of this Association that $5 a year will drive them out, I say to them, "Go, children, and God bless you; go as far as you can and as quickly as you can." [*Applause.*]

Mr. Diven. As I understand the amendment now proposed, it will increase the revenue about $1 000?

Mr. Metcalf. Assuming no losses of membership.

Mr. Diven. The losses will be inappreciable. Will that be sufficient to meet the deficiency?

Mr. Metcalf. It will be sufficient to meet the annual cost; it may not be quite sufficient to take care of the deficit of this year, and it was for that reason we suggested the other measure, giving the Executive Committee power to ask for contributions of $1 if they have to. An increase in the dues from $3 to $4 and from $15 to $20 would increase the income of the Association by about $1 400, assuming there were no losses in membership.

Mr. F. H. Hayes favored $15 as enough for the dues of the associate members.

Mr. Patrick Gear proposed separating the motion and allowing the associate members to vote on the section affecting their dues.

Mr. Macksey. If there is no objection I will withdraw my original motion and make it as two motions. In the first place, I move as an amendment to the amendment of the Constitution now before the house, that the rate for the active members be set at $4 instead of $5.

The motion was adopted unanimously.

Mr. Macksey. I now move as a further amendment to the amendment of the Constitution now before the house, that the dues for associate members be $20 instead of $25, as in the original amendment. And I move as an incidental motion that the associate members present be given the privilege of the floor to discuss this amendment.

It was voted to give the privilege of the floor to the associate members.

Mr. Wm. Woodburn. I think most of the associate members would be perfectly willing to pay $20. It is a very small amount in the course of the year for the benefit we receive. And, not only that, I think very few appreciate the value of the Journal as an advertising medium, and I think we should come out stronger in our support of the Journal in advertising. When we are now taking a half or a quarter of a page, let us take a whole page, and make the Journal the paper that it should be and more nearly self-supporting. I understand that the bulk of the deficit is on account of the Journal, but I feel that the Journal is a valuable advertising medium. Mr. Diven thinks it is more of a complimentary proposition on the part of the advertisers, but I know differently. The Journal has a circulation of over 1 000 copies. It not only comes in and is read, but it is a paper that is filed away and is used for reference from time to time, and not only in New England, for but half of our membership, I understand, is in New England, and the other half is scattered all over the country. A man in southern California, for instance, wants to buy valves; he is a member of the Water Works Association, and he looks in the Journal. I think we should get together and put our shoulders to the wheel and help on the advertising end.

Mr. Van Winkle expressed the belief that not six associate members present had authority to bind their firms.

Mr. Hays. I might say that I am one sixth of them, and I am willing to pay my $20.

Messrs. Coulters, Caldwell, Wood, and others, stated that they could speak for their firms, and believed most of the associate members present could. Expression was given of the appreciation of the value of the Association to their firms. All favored the proposed increase to $20.

Mr. Macksey's motion as an amendment to the amendment of the Constitution before the house, that the dues of associate members be $20 instead of $25, was adopted.

Mr. Sherman then moved that the amendment to the Constitution as amended by changing the annual dues of active members from $5 to $4, and those of associate members from $25 to $20, be adopted, so that it shall read as follows:

Sect. 2. The annual dues shall be —

For Members,	$4.00
For Associates,	$20.00

and this motion was adopted unanimously.

Mr. Metcalf. I will move that the Executive Committee be authorized to ask for contributions of one dollar from the members in case it finds it desirable to do so, to meet the present deficit, in preference to selling the securities of the Association at the loss which would be involved.

The motion was unanimously adopted.

Mr. Coggeshall. I have the interests of this Association at heart, the same as every one present has, and somehow or other I have got into the mood of giving, in common with all of you. There is scarcely a week goes by but we are asked to make a subscription to one fund or another fund. I have been very happy in the honors that this Association has given me in years past, and two years ago you made me an honorary member, so that I am free from dues. But I propose to send the Association within a day or two a check for $5 as a present from an honorary member, and perhaps some others will do the same. [*Applause.*]

The President. The following letter has been received from Professor Swain, which I should like to read:

NOVEMBER 28, 1917.

My dear Mr. Saville, —

It seems most desirable for the good of the country that students in engineering schools who are drafted for service should, to such extent as may be possible, be detailed back to their respective schools to pursue their studies. Otherwise, we shall be seriously depleting our supply of trained applied scientists.

Enclosed is a copy of a letter which it is proposed to send to Secretary Baker. Signatures are being asked from the various technical schools, and they are desired from the presidents of the various engineering societies.

I earnestly hope that this will appeal to you and that you will sign the letter as president of your society and return it to me as soon as possible. If practicable, I should appreciate a telegram from you expressing your approval, so that if desired a single letter may be sent to Secretary Baker with all authorized signatures, leaving the individual letters to be sent later if desirable.

If you could secure favorable official action by your Board of Directors, it would also help.

I sincerely hope you will help in this movement.

Yours very truly,

(Signed) GEO. F. SWAIN.

MR. DIVEN. Action has already been taken by the War Department, so I am informed, doing this very thing.

On motion of Mr. Macksey, the communication was received and placed on file.

Mr. Frank A. Barbour, supervising engineer, gave a description, illustrated by stereopticon views, of recent construction work at the Ayer Cantonment, and Mr. Leonard Metcalf spoke of the wonderful work which has been done at Ayer and other camps.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at Norumbega Park, Newton, Mass., Wednesday, June 13, 1917.

Present: Vice-President Samuel E. Killam, presiding, and members Frank J. Gifford, Lewis M. Bancroft, George A. King, Carleton E. Davis, and Willard Kent.

Three applications for membership were received, viz., Walter Elwood MacDonald, city water works engineer, Ottawa, Canada; Herbert T. White, water registrar, Revere, Mass., and Robert C. Wheeler, civil engineer, Philadelphia, Pa., and they were by unanimous vote recommended therefor.

The President was by vote authorized to appoint the following committees for the September convention, viz., — Committee on Literary Program, Local Members' Reception Committee, Ladies' Reception Committee, Citizens' Reception Committee, Associate Members' Committee.

A letter from Mr. George C. Whipple, president of the Boston Society of Civil Engineers, recommending the adoption by the Association of a resolution favoring Prohibition during the continuance of the present war, together with a letter of endorsement from Caleb Mills Saville, President of this Association, was presented, and it was voted that the adoption of said resolution be recommended to the Association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., November 14, 1917.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, Frank J. Gifford, Lewis M. Bancroft, George A. King, and Willard Kent.

Five applications for membership and one for associate membership were received and unanimously recommended therefor, viz.,

For Active: G. Ferullo, contractor, Boston, Mass.; Herbert M. Tucker, manager, Hartford (Vt.) Water Works, Lebanon, N. H.; Charles Sing Denman, general manager, Des Moines Water Co., Des Moines, Ia.; A. A. Laflin, superintendent Water Works, St. Stephens, N. B.; V. Adolph Zehr, civil engineer, Wilkinsburg, Pa.

For Associate: Eugene F. Leger, Allston, Mass.

A communication from the American Society of Mechanical Engineers, inviting this Association to appoint a delegate to attend a public hearing for the discussion of the Power Test Codes of that Society, was received, and the President was, by unanimous vote, authorized to appoint a delegate thereto.

A letter from Percival H. Mitchell, relative to the remission of dues of Lieut.-Col. C. H. Mitchell and other members of this Association now in active service in the Allied Armies, was presented, and, after discussion, it was unanimously voted that the Treasurer be and hereby is authorized to pay from the treasury of the Association the dues of members in active service during the continuance of the war.

The Secretary was directed to prepare a list of the names of members so engaged.

The Secretary was, by vote, directed to extend the thanks of the Association to non-members of this Association who contributed to the success of our convention of 1917.

The Secretary presented a letter from his assistant, requesting increased compensation for services; after discussion, on motion of Mr. Macksey, seconded by Mr. Gifford, it was *voted*, that the rate of compensation of assistant to the Secretary be ninety dollars per month, and that the duties include such assistance as the Editor and Advertising Agent require.

On motion of Mr. King, seconded by Mr. Killam, the President was authorized to appoint a special committee to consider the question of finances of the Association, and to make recommendations as to future methods of handling same. The President subsequently appointed as that committee Messrs. Leonard Metcalf, Charles W. Sherman, R. C. P. Coggeshall, Carleton E.

Davis, Samuel E. Killam, Henry V. Macksey, President Caleb M. Saville, Treasurer Lewis M. Bancroft, and Secretary Willard Kent.

Voted, that the thanks of the Association be given to Mr. Charles W. Sherman for his able and unrequited services rendered in editing the September JOURNAL of the Association.

Mr. George A. King presented, in writing, the following proposed amendment to the Constitution of the Association, and, by unanimous vote, it was recommended for adoption at the December meeting of this Association.

Strike out the whole of Section 2 of Article III, and make it to read as follows:

Sect. 2. The annual dues shall be —

For Members,	$5.00
For Associates,	25.00

Voted, that Mr. Henry A. Symonds be and hereby is appointed Editor of the JOURNAL of the Association, to fill the vacancy caused by the death of Editor William S. Johnson.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association, December 12, 1917, at headquarters, Tremont Temple, Boston, Mass.

Present: President Caleb Mills Saville, and members Carleton E. Davis, Samuel E. Killam, Henry V. Macksey, Frank J. Gifford, Lewis M. Bancroft, George A. King, and Willard Kent.

Four applications were received, two for active, viz., Frederic E. Beck, engineer, Consolidated Water Co., of Utica, N. Y.; John Y. Lavery, city engineer, Summit, N. J.; and two for associate membership, viz., Donaldson Iron Company, Emaus, Lehigh Co., Pa., and Hammond Process Company, Boston, Mass., and they were by unanimous vote recommended therefor.

The report of the special committee, appointed at the last meeting of the Executive Committee, " To consider the finances of the

Association and to make recommendations as to future methods of handling same, " was read, and it was unanimously *voted* that the report be accepted and that the chairman of the committee, Mr. Leonard Metcalf, be requested to present the same at the meeting of the Association this day. It was further voted that the thanks of the Executive Committee be given to Mr. Metcalf in expression of its appreciation of the valuable time and labor expended on the report.

The salary of the Editor was by vote fixed at three hundred dollars per annum, and that of the Advertising Agent at one hundred dollars and ten per cent. on new advertisements.

Requests that they be placed on the free mailing list of the JOURNAL of the Association were received from the Librarian of the University of Missouri and from the Public Service Commission of New Hampshire, whereupon it was *voted*, that the first request be referred to the Editor and that the second be laid on the table.

Adjourned.

Attest: WILLARD KENT, *Secretary*.